RAPTOR LAKE REVIEWS
Intel i9-13900K and i5-13600K tested **PG.74 & 76**

PC HDR UPDATE
How to get the best visuals from your PC **PG.52**

WINDOWS 11 BOOSTS
Go faster for free with OS & GPU driver tips **PG.62 & 70**

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STEP-BY-STEP GUIDE
Create the **ultimate gaming PC**
PG. 16

BUILD IT!

8K GAMING MONSTER

Build an RTX 4090 powerhouse

- Max it out with Intel's i9-13900K
- Play Cyberpunk 2077 @ 100+fps

DDR5 RAM
Save cash with our overclocking tips **PG. 56**

FUTURE Digital Edition

GEAR OF THE YEAR
The 15 best PC products of 2022 ● 10 five-star reviews ● The top pre-built PCs ● The components to Do-It-Yourself
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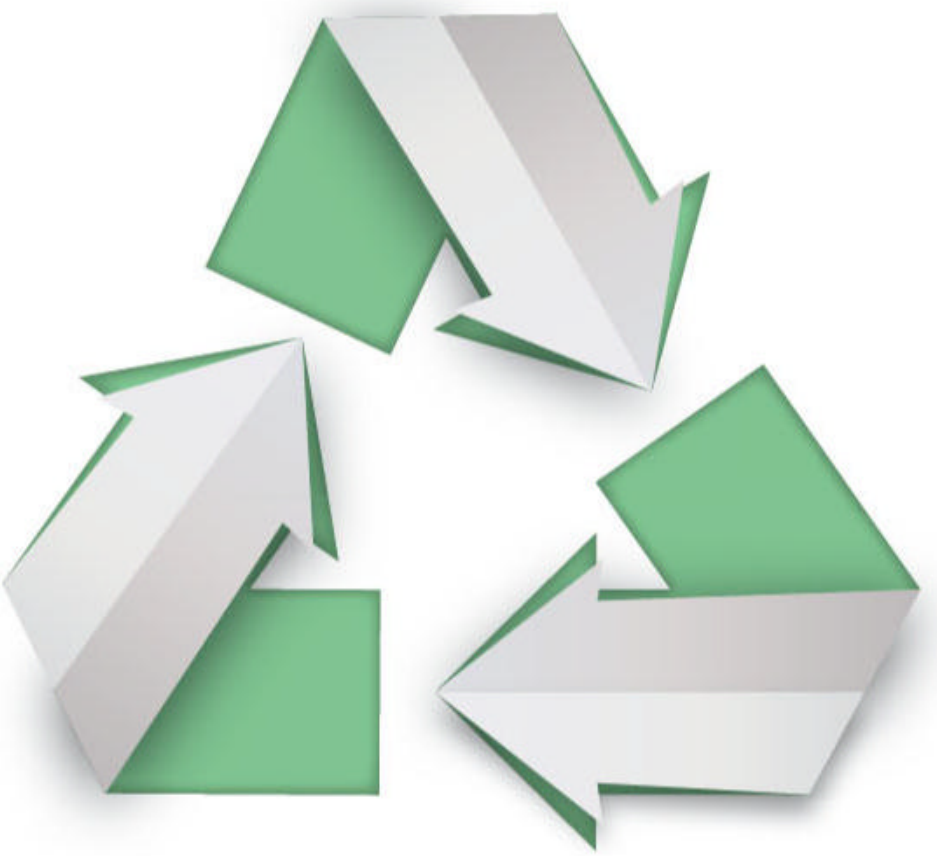

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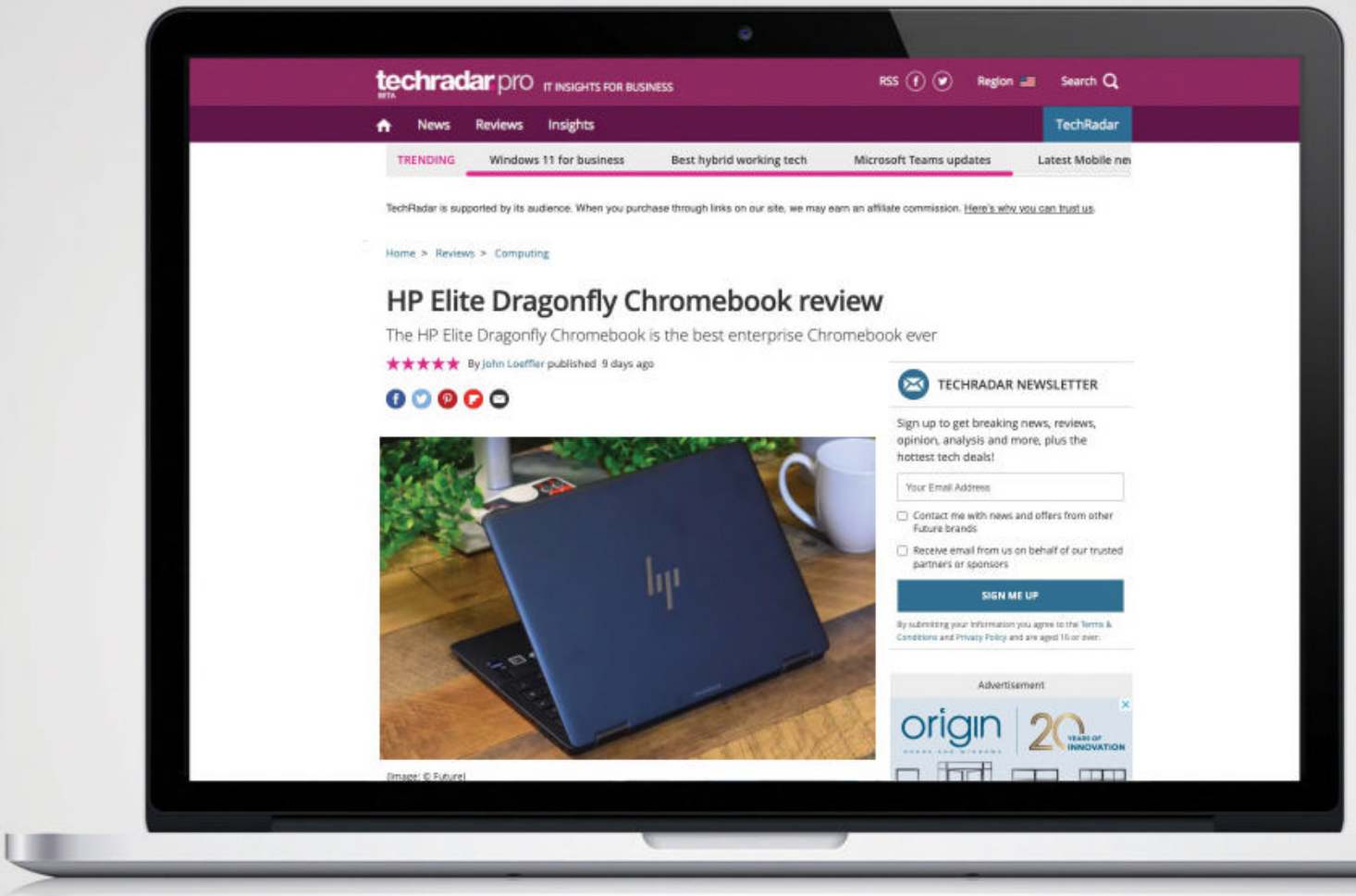

Best practices and solutions

Up-to-the minute news

In-depth reviews

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inside

HOLIDAY 2022

SCAN TO GET THE TOM'S HARDWARE WEEKLY NEWSLETTER

16 8K GAMING MONSTER

QUICKSTART

8 THE NEWS
Nvidia's hot new GeForce RTX 4090; Gamers adopt Win11 (slowly); Razer Edge handheld goes 5G.

12 THE LIST
Best power supplies for PC gaming.

Gold certified in efficiency, and with a Cybenetics A noise rating, the BeQuiet! PSU is ultra-quiet.

40 SUBSCRIBE TODAY
Subscribe to *Maximum PC* and receive a gift in time for Christmas.

R&D

61 HOW TO
Build an audiobook or podcast server; Install and uninstall GPU drivers the correct way.

62 WINDOWS 11 22H2
We look at all the new features of the first major update for Win11.

LETTERS

14 DOCTOR

94 COMMENTS

IN THE LAB

74 INTEL CORE i9-13900K

78 AMD RYZEN 7 7700X

82 INTEL ARC A750 LIMITED EDITION

90 GOTHAM KNIGHTS

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32 GEAR OF THE YEAR
Our pick of the favorite pieces of tech that we've reviewed in 2022.

42 INTEL ARC ALCHEMIST
Turning silicon into gold. *Jarred Walton* examines what makes Alchemist tick.

52 HDR ON THE PC
Jeremy Laird looks at the current state of HDR technology on the PC.

56 LIFTING THE LID ON DDR5
The latest RAM tech is here, but what difference does it actually make?

A NEW UNIVERSE AWAKENS

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4K ULTRA HD™ AND DIGITAL

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PG-13 SEQUENCES OF STRONG VIOLENCE, INTENSE ACTION AND SOME LANGUAGE

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Guy Cocker

NEXT GEN HAS ARRIVED!

WELL, HERE WE ARE. We've spent the last few issues teaching you how to build budget PCs under $1,000—a great exercise, as that hasn't been possible for the best part of two years thanks to inflated prices. But with that anomaly behind us, this issue we're able to welcome a brand new generation of CPUs and GPUs and put them into a new high-end build, starting on page 16. We're talking top-of-the-line products from Nvidia and Intel powering the fastest gaming PC currently available.

We already gave the Nvidia RTX 4090 our highest score in the form of a 'Kick-Ass' award in our last issue, so we knew we were dealing with a gaming powerhouse there. But we were relieved to find Intel building on the success of its excellent Alder Lake chips with its brilliant 13th-gen Raptor Lake updates. While the Core i5-13600K is enough for the vast majority of gamers, even those running the 4090, we couldn't resist going all-out with the higher-end Core i9-13900K in our build. After all, it's been over six months since we last did a proper 4K gaming build.

So, is it worth building such a system? There's a certain real-world factor at play—at the time of writing, a few weeks after the release of the RTX 4090, the Founders Edition is still out of stock while partner boards sell for at least 10 percent more than RRP. Our system also costs more than $3,750—not crazy by any means, but a significant premium over a last-gen Intel 12900K/Nvidia RTX 3090Ti system that will also run games pretty damn well.

But this is *Maximum PC*, and I imagine a good chunk of you just want to be able to game safe in the knowledge that you're playing on the most powerful system available. We're talking double the TFLOPS performance of the 3090Ti, eight times that of the PS5—and that's without overclocking. For people who are happy to spend the money needed to be at the cutting edge, this system comes with a massive recommendation. The raw performance increase is insane and the promise of what can be achieved with DLSS 3 means that 4K Ultra ray-traced gaming isn't just achievable, it could soon become the norm.

Elsewhere, we look back at 2022 and name our Gear of the Year—the best products that have come through our labs over the last 12 months. As Christmas arrives, it's a good time to remind ourselves of some of the things we might want to treat ourselves to—I've personally just invested in the Alienware 34 AW3423DW OLED gaming monitor to try and make myself spend more time relaxing and playing games!

As well as Intel's new processors, we're also reviewing the mid-range AMD Ryzen 7 7700X, following on from the Ryzen 9 7950X last issue. I won't spoil the review, but there's a feeling that AMD isn't quite competing with Intel on price-to-performance this generation—a price drop on AMD's side could tip the balance and get more people moving over to Zen 4. We're looking to produce a build with AMD's new silicon soon, preferably when we can also get our mitts on its new RDNA 3 graphics cards, so look out for that in the new year.

Given the strength of this month's build, it will take a lot to topple Intel and Nvidia, but we're always happy to be surprised by Team Red. Enjoy the issue!

Guy Cocker

Guy is Maximum PC's Editor-in-Chief. He built his first gaming PC in 1997 to play Tomb Raider *on 3dfx, and has been obsessed with all things PC ever since.*

↘ submit your questions to: editor@maximumpc.com

THE NEWS

New graphical king

Power cables under strain from new monster GPU

THE MIGHTY Nvidia GeForce RTX 4090 ($1,599) has finally landed, and it's a monster. The card has quickly dominated the benchmark tables, proving virtually unbeatable, especially at higher resolutions. Nvidia claims the card is over twice as fast as the RTX 3090 Ti.

It's not just a gaming beast either, it has also proved to be the world's best password-cracking card, thanks to all that raw GPU power. Using a benchmark called Hashcat, a researcher found the card to be over twice as fast as the previous champion, the RTX 3090. As impressive as it is, AMD's RDNA 3 cards are just around the corner, and we'll get an RTX 4090 Ti at some point too. However, for now, the RTX 4090 rules the roost.

As welcome as the 4000-series cards are, not everything has gone smoothly for Nvidia. We were expecting trouble with the amount of power the RTX 4090 can chew through. It's officially ranked as having a TDP of 450W, however, it can be pushed to more than that, especially if you overclock it. To supply that power, the card uses a 12VHPWR socket. This 16-pin socket can, in theory, deliver 600W. It's part of the ATX 3.0 PSU specifications and was added to cope with the expected new generation of power-hungry cards. It has 12 power pins, and four smaller pins for sideband signals. These enable the graphic card to detect what PSU is connected, and configure the initial power at system start, and the maximum sustained power draw accordingly.

The PCI-SIG, the body that manages PCI standards, warned back in September that using an ATX 2.0 PSU with an adapter cable to run 12VHPWR sockets was problematic. If you use two 8-pin connectors to power your 12VHPWR cards you can easily overload things. Each 8-pin connector has a maximum designed draw of 150W, so you've doubled the load. If you use three 8-pin connectors to a 12VHPWR (more sensible), you can draw up to 450W, however, the load is not equally split across the three outputs, which leads to uneven thermals. Soon after the RTX 4090 arrived with testers, problems started to emerge. Things got toasty and, in some cases, melty.

> Soon after the RTX 4090 arrived, things got toasty and, in some cases, melty.

To allow the use of ATX 2.0 PSUs, Nvidia shipped its 4090 cards with adapter cables, converting four 8-pin plugs into one 12VHPWR plug, which should theoretically be adequate. But this adapter wasn't the best made of items and different types have been discovered, some with cables rated for 150V instead of the expected 300V, and others that are poorly soldered.

The situation isn't helped by the card being massive, meaning the cable often has to be physically bent at alarming angles to sit properly. Nvidia is still investigating the adapters, but it's clear that several sub-standard ones have found their way into customers' hands. It doesn't take many such failures to cause alarm.

Nvidia should have seen this coming. The upshot is that if a graphics card uses a 12VHPWR connector, you need to know what you're doing to run an ATX 2.0 PSU with an adapter. But if you've dropped all that cash on the current king of graphics cards, spending more for a PSU the card deserves is good practice. AMD won't be using 12VHPWR cables for its RDNA 3 cards but will stick to dual 8-pin connectors for its reference cards. Its partners, if they have any sense, will follow suit.

Meanwhile, there is another launch oddity. The original 4000-series range consisted of three cards; alongside the 16GB version of the RTX 4080, there was going to be a 12GB version. This was never popular as it used a smaller GPU and offered about 30 percent less performance than the 16GB version. The name proved confusing, as previous generations of cards using different GPUs earned different names. Pundits pointed out that the card should have been called an RTX 4070 instead.

Nvidia has 'unlaunched' (its word) the RTX 4080 12GB. It was always a partner-only card, so Nvidia didn't lose any stock itself, but it can't have pleased any partners that had already designed and built cards. These niggles aside, we'll be going into the holiday season with two cracking next-gen families of cards, which while not cheap, are a big step up in performance. Sounds good to us. **–CL**

GAMERS ADOPT WIN11, SLOWLY

ONLY 1/4 OF STEAM USERS

DO YOU RUN WINDOWS 11? It seems that the initial reluctance for gamers to make the jump is slowly eroding. Steam keeps track of who's running what, and Windows 11 has reached nearly a quarter of all users. Hardly dominating, but at the start of the year, it wasn't much over ten percent. The reluctance to move hasn't been helped by bugs and its initial design. Its security features, specifically the virtualization-based security, impacted game performance, although thankfully it can be disabled.

Win11's latest update 22H2 has introduced a new bug for AMD rigs: if you have a high-end Ryzen with multiple chiplets (Ryzen 9 7900X and 7950X) then the Windows thread scheduler gets 'confused', resulting in lost performance. If you turn off one CCD or multi-threading, you can gain up to 30 percent gaming performance. We await a proper fix. AMD seems to be particularly badly served by Win11—last year, another bug robbed all its processors of up to 15 percent performance until it was patched. Windows 11 will rule eventually, but Microsoft hasn't made it a tempting proposition for gamers. **–CL**

OFFICIAL SECURITY FOR THE IOT

Every smart gadget is a potential security risk, but we are finally going to see some official action with a proposal that all devices are given a cybersecurity rating along the lines of the Energy Star program. The project is being run by the National Institute of Standards and Technology (NIST) and the Federal Trade Commission (FTC). A set of standards are in development and, eventually, a 'globally recognized' label will be applied to every device.

A barcode will allow you to see what standards are being met on your device. Initially, the project will focus on routers and security cameras. This is good news, but it has come too late and will take some time to filter through. There are over 13 billion IoT devices in the world and over 2.8 billion in the US alone. It won't be much use if you don't change the default passwords, of course, but maybe it will stop the production of pacemakers that can be hijacked and kill you (yes, that actually happened). **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

CHIPS IN NEW YORK
Micron is to invest $100 billion to build a fabrication plant in upstate New York.

FLYING CARS
Alef Aeronautics plans to build the "first real flying car", the VTOL. Deposits for the $300,000 vehicle are being taken.

INFINITE ART
Microsoft Office is to get a new feature called Microsoft Designer, which uses AI to create art, in any amount, of anything.

TRAGEDIES

MUSK RUINS ASTRONOMY
SpaceX v2 has plans to launch another 30,000 satellites. The FTC has been asked to step in.

SALES SLOWDOWN
Shipments of smartphones are on course to be the lowest since 2014. Cost of living means people are holding on to them.

INTEL CUTS STAFF
Intel is to let employees go due to "worsening economic conditions". Some chips are also expected to be dropped.

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THE EMPTY METAVERSE

New hardware, but few users and rising losses

MARK ZUCKERBERG'S vision of the metaverse is big and bold, but currently floundering. Meta has invested billions of dollars and assigned thousands of people to create the Utopian dream that Zuckerberg called his 'Holy Grail'. The platform's flagship game, *Horizon Worlds*, is still buggy, although avatars do now boast legs. There are barely 200,000 users, under half the projections. Most user-created worlds are never visited, and an internal memo described it as an "empty world, a sad world". Consequently, most visitors leave after a month.

Behind the scenes, there are rumors of employee dissatisfaction, strategy changes, and a lack of understanding of what the metaverse is trying to achieve. Even inside Meta, participation is low, leading to managers pushing employees to use it to boost engagement. The troubles are reflected in Meta's stock price, which has fallen by over 60 percent this year. The losses for Reality Labs, the division running the metaverse, are $3.67bn for Q3 2022 and are expected to get worse.

Meanwhile, we have the first hardware specifically designed for the metaverse, the Meta Quest Pro ($1,499). A departure from previous designs, it has full-color pass-through with four cameras to enable mixed reality, with a resolution of 1,800x1,920 per eye. A more affordable headset is also due next year. Meta has added Horizon Workrooms, hoping people will take their work into the metaverse. But even the founder of Oculus, Palmer Luckey, couldn't summon any enthusiasm, conceding the metaverse "is terrible today, but it could be amazing in the future".

We'll see whether people really do want to live out large chunks of their lives in the virtual creation of a corporation, though we suspect not. Meta, or something similar, may be part of the future, but for now, it's running on promises and hopes. **–CL**

COLORFUL NEW SURFACE PRO 9 MIXES INTEL & ARM

Laptop-tablet hybrid reaches version 9

MICROSOFT'S FLAGSHIP Surface Pro tablet has reached version nine, offering laptop performance with the flexibility of a tablet, the company claims. The biggest change is the inclusion of ARM-powered varients, with the Intel and ARM versions being folded into one product line. At first glance, it looks similar to version 8, with the same 13-inch PixelSense screen with a resolution of 2,880x1,920 pixels, minimal bezel, and built-in adjustable kick-stand.

Prices start at $1,000. For this, you get a 12th-generation Intel Core i5-1235U CPU with 8GB of RAM, and 128GB of solid-state storage, available in platinum color. There are six further Intel versions, with different processor, memory, and storage configurations. The top model ($2,600) sports a Core i7-1255U, 32GB of RAM, and 1TB SSD. These models are also available in sapphire, forest, and graphite colors.

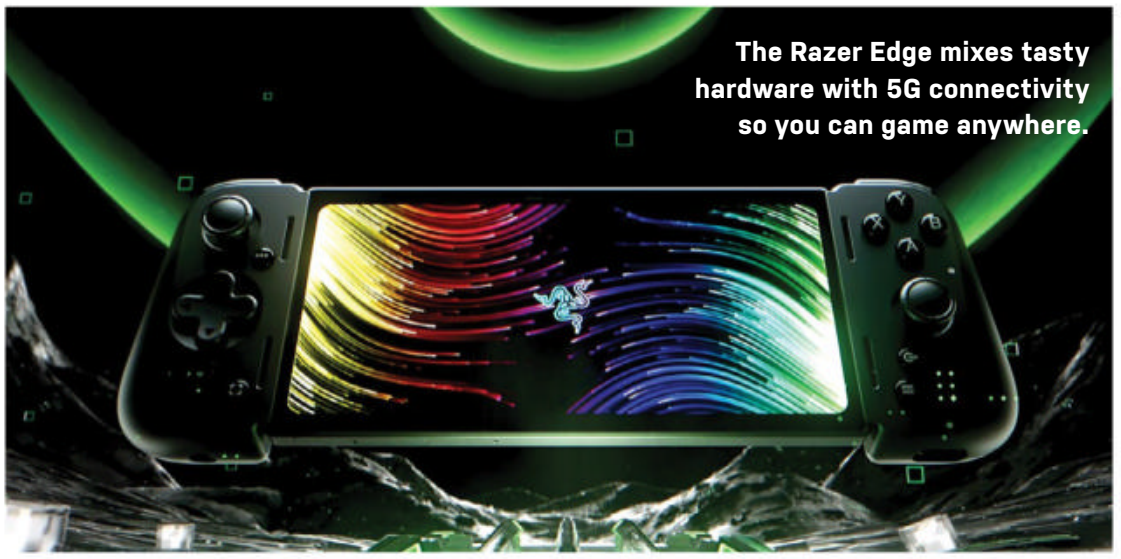
The cheapest ARM version is $1,300. This uses a Microsoft SQ3 processor, which is an overclocked eight-core Snapdragon 8cx Gen 3 with 8GB of RAM and 128GB of storage. Three further ARM models top out at 16GB of memory, and 512GB of storage ($1,900). The Intel systems are Wi-Fi, while ARM ones get 5G too. Ports are either two Thunderbolt 4 for the Intel models or two USB-C for ARM ones. There's an optional keyboard ($180) and stylus ($130), or both for $280. The Surface Pro 9 weighs 1.95lbs (883g), and measures 11x8in.

Offering ARM-based systems shows that Microsoft is getting confident using the hardware, even if Windows 11 isn't the perfect OS. There aren't many laptops or tablets with mmWave 5G, as this requires non-Intel hardware. The Surface Pro 9 is sleek and stylish; our only gripe so far is the lack of a 3.5mm jack. **–CL**

Razer Edge to go 5G

READY FOR ANOTHER HANDHELD CONSOLE? The Razer Edge makes a bold claim—the world's ultimate gaming handheld for PC games, mobile games, and console games. This high-powered beast runs an eight-core 3GHz Snapdragon G3x Gen 1 with active cooling, designed exclusively for the Edge, coupled to 8GB of LPDDR5 memory and 128GB of storage. The screen is a 6.8-inch OLED touchscreen running at 144Hz with a resolution of 2,400 by 1,080, and a touch sampling rate of 288Hz. The controllers clip onto either side and include haptic feedback. Razer Edge runs Android 12 for mobile gaming, but you can also run Xbox Cloud Gaming, and GeForce Now streaming services. With controllers attached, it's fairly chunky at 14.1oz (401g) but the 5,000mAh battery is promised to be good for 30 hours of play.

The Wi-Fi 6E version costs $399. There will also be a 5G version (both sub-6, and mmWave) to follow at an, as yet, undisclosed price. This uses the Verizon network exclusively. The Razer Edge goes up against the Steam Deck and Logitech G Cloud, another new Android-based handheld gaming device. Wi-Fi gaming needs a sturdy Wi-Fi signal, which limits mobility somewhat, and for true portable gaming, you need 5G. This is where the Razer Edge scores highly—it has the power to run games fast, and the connectivity to do that anywhere. It will be available in January next year and will be the most powerful handheld gaming device you can get, for a while anyway. It's not exactly cheap though, especially when you add the cost of streaming subscriptions and 5G fees, which we've yet to see detailed. **–CL**



The Razer Edge mixes tasty hardware with 5G connectivity so you can game anywhere.

Google Incognito mode... isn't

Chrome's Incognito mode stops third parties from seeing your data, right? Nope! It claims you can "browse the web privately", but you can't. Three Chrome users got together to launch a class action suit and now court rulings have revealed that Google was aware it overstated the privacy aspect. Last year, a marketing chief asked Google CEO Sundar Pichai if they should make it "truly private", and raised concerns over the 'fuzzy' language used in descriptions.

What's clear is that Google knew all along it wasn't really private and chose to do nothing. If Google loses, it could be paying damages, although there would be millions of potential claimants, which could be awkward. **–CL**

Digital vehicle tags

California has joined Arizona and Michigan in allowing digital license plates. You can now fit a monochrome LCD screen on the rear of your vehicle. Currently, only one company, Reviver, has DMV authorization. It offers two versions, the battery-powered plate costs $99 to install, and $20 a month or $215 a year for four years. A hard-wired option includes GPS, which comes in handy if your car is pilfered—you can change the plate to show 'stolen'. This costs $150 to install, and $25 a month or $275 a year for four years. Both have low-power LTE to connect to the DMV's cloud server and can display (approved) personal messages. There are some obvious security issues though. **–CL**

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Jarred Walton

TECH TALK

Nvidia's RTX 4090 16-pin Adapter Woes

LAST MONTH, we finally got a taste of what Nvidia's Ada Lovelace architecture and the RTX 4090 GPU have to offer. Yet already there are reports of failing cards. For the second major architecture launch in a row, Nvidia's greatest graphics cards are raising power-related concerns.

That's not particularly surprising, given the new king of GPUs has a base power draw of 450W and custom cards can push that up to nearly 600W. But there's a potentially bigger problem, and it involves Nvidia's 'quadropus' 8-pin to 16-pin adapter cable.

All RTX 4090 cards appear to come with the same adapter cable, bearing an Nvidia logo. On one side is the new 16-pin 12VHPWR ATX 3.0 PCIe 5.0 connector and, on the other, are four traditional 8-pin PEG connectors, each capable of providing up to 150W of power—potentially up to 600W of power through a single cable. How convenient!

Except when you look at the 16-pin connector and compare it with the existing 8-pin connector, you'll notice that the new connector is physically about two-thirds the size of the old connector. Think about that for a moment—four times the power coming through a smaller physical connection. Presumably, PCI-SIG, the ruling body that helps to define PCI-related standards, knows what it's doing. Maybe.

The problem is that the 16-pin connector carries so much current and power that if it doesn't make a secure connection, things could go wrong. Or at least that's one potential theory. So far, there have been at least a few reports of melted connectors posted online. With potentially thousands or even tens of thousands of RTX 4090 cards in the hands of users, there are bound to be a few problems. What's unclear right now is how widespread the problem is, though Nvidia is aware of the reports and is in contact with the owners.

CableMod, which makes custom-sleeved cables, has some guidance on the 12VHPWR connector. "It appears that bending the wires too close to the connector could result in some of the terminals coming loose or misaligning within the connector itself. This may lead to an uneven load across the other wires, increasing the risk of overheating damage. This is substantially higher if the bend is horizontal in relation to the connector orientation (left to right)." It recommends only bending cables starting at 35mm away from the connector. Considering the size of many RTX 4090 cards, taking that advice may prove impossible in many cases.

Pictures posted online so far have shown some 'horizontal bend' near the connector. This wouldn't normally be a problem, but it's possible the extra stress on the connection could cause the pins inside the connectors to become loose. If that happens, electrical arcing could occur, which could then cause heat and melted plastic.

This isn't the first time Nvidia has had launch issues with a new halo product. Previous-generation Ampere RTX 3080 and RTX 3090 cards experienced instability at launch—some models had problems so severe that a recall and replacement program had to be instituted. EVGA had some well-publicized card failures that could have influenced the CEO's decision last month to exit the market.

Right now, the RTX 4090 has only been in the wild for a few weeks. These could end up as isolated incidents or be a preview of what's to come as more RTX 4090 cards are used for weeks and months on end. We can only imagine the horror felt by the owners whose $1,600 graphics cards are suddenly dead and in need of an RMA. Hopefully, Nvidia and its partners can get to the root cause and issue further guidance while taking care of early adopters.

CableMod suggests not bending the adapter closer than 35mm from the connector. Not easy here!

For now, our advice is to ensure your 16-pin connection is secure and avoid any stress on the cables. If you can find a PSU with a native 16-pin connection or a right-angle adapter, that may help. However, finding such parts might prove to be just as difficult as finding an RTX 4090 in stock at MSRP.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

THE LIST

BEST POWER SUPPLIES FOR PC GAMING

WHILE THE RUMORED 600W+ power requirement for the RTX 4090 didn't quite pan out, Nvidia does recommend at least an 850W power supply for this generation's top card, up from 750W for the 3090. So there are probably quite a few people out there looking to upgrade their rig. Regardless of whether you're buying a new system or upgrading though, it's always a good idea to have a good PSU at the heart of your system. These are five of the ones we recommend for gamers.

5 SILVERSTONE SX1000 PLATINUM

www.silverstonetek.com, $305

The best small-form PSU on this list doesn't stop it from having every connector a gaming PC builder needs, at least for the next few years. It's completely modular, which is handy for compact builds as you can leave out cables to save space. It can be pushed hard too—we monitored 1500W capacity in our testing. The double ball-bearing fan also keeps it cool.

4 CORSAIR AX1600I

www.corsair.com, $610

If you're going to be pushing your PC by filling a computer with the most power-hungry components, and then driving them hard via overclocking, then this is the PSU for you. As well as its ridiculous 1600W capacity, it's highly efficient, thanks to GaN MOSFETs, which can offer up to 99 percent efficiency. It is remarkably quiet too, thanks to its high-quality FDB fan.

3 BEQUIET! PURE POWER 11 FM 550W

www.bequiet.com, $90

If you're running an average system without the need for stupid power requirements, this PSU from BeQuiet! is the one to go for. It's 80 PLUS Gold and Cybenetics Gold-certified in efficiency, plus it has a Cybenetics A noise rating, meaning it's ultra-quiet. But perhaps best of all is that it's priced at under $100, which is excellent value for such a high-quality PSU.

2 SEASONIC PRIME TITANIUM TX-1000

www.seasonic.com, $310

If you're considering a high-end GPU upgrade in the next couple of years then it makes sense to go for at least 850W, if not 1,000W for proper future-proofing. Seasonic's base platform is used by many other manufacturers including Corsair. This PSU is crazy efficient and quiet, thanks to its fluid dynamic bearing fan, and also comes with a generous 12-year warranty.

1 CORSAIR RM750X

www.corsair.com, $135

While we're all getting carried away at present with 850 and 1,000W PSUs, the truth is that 750W will still be more than enough for most people. The RMx line is among the best in the PSU market, combining high performance and reasonable prices. This model uses a magnetic levitation fan for quiet operation, plus high-quality Japanese caps, and has a long 10-year warranty.

© SILVERSTONETEK, CORSAIR, BEQUIET, SEASONIC

Jeremy Laird

TRADE CHAT

That prediction didn't work out so well…

ROUGHLY A YEAR AGO, I predicted 18 months of awesomeness for the PC. "A rapid-fire product assault is coming from AMD, Intel, and Nvidia, the likes of which we've rarely seen," were my exact words. There's still one major launch to come, but with four out of five reveals under our belts, it hasn't worked so well. Am I disappointed? Yup. But let's keep some perspective.

The five launches are, of course, new CPU families from Intel and AMD respectively, graphics cards from AMD and Nvidia, and Intel's long-awaited entry into the gaming GPU market. As I write this, we've had at least partial launches of everything bar AMD's upcoming Radeon RX 7000 series graphics. And it's been pretty patchy so far.

So, what happened—apart from me simply being wrong? There hasn't been a single overarching theme. It's a mix of failure to execute, unrealistic expectations, unusual market conditions, and cynical production planning. It's just unfortunate that it has all come together at the same time.

The failure to execute obviously applies to the dumpster fire that is Intel's Arc graphics launch. Had those GPUs rolled out on time, they would have been merely disappointing. But arriving a year late has compounded Arc's woes. The hardware isn't awful, which gives me hope for the future. But Intel needs to get a grip of its graphics drivers to have any hope of competing with AMD and Nvidia.

As for the unrealistic expectations, those apply to AMD's Zen 4 architecture and the Ryzen 7000 CPU family. In terms of headline features, including 5nm production tech and 5GHz-plus clocks, Zen 4 delivers. But its underlying architecture is only a minor tweak compared to Zen 3. And AMD didn't up the core count. So, it's an incremental improvement rather than a revolutionary step forward.

Moving on to Nvidia's new GeForce RTX 40 graphics cards, Nvidia pretty much delivered on

> If the latest rumors are accurate, even RDNA 3 won't be as thrilling as we'd hoped.

Nvidia's RTX 4080 is poor, but 2022 hasn't been all bad.

my expectation that certain SKUs would be capable of double the performance of the RTX 3000 series. The new RTX 4090 is a monster. But Nvidia positively screwed the pooch with the RTX 4080 boards and I await further horrors with the rest of the 40 Series. That's at least in part down to market conditions. Nvidia has a mountain of old 30 series graphics cards it needs to shift, just as demand for GPUs is cratering thanks to a sudden implosion of crypto mining demand and an increasingly sickly world economy.

Of all the launches so far, Intel's Raptor Lake has probably come closest to meeting expectations. As you can read in our reviews of both the Core i9-13900k and Core i5-13600K this issue, by ramping up both the core counts and clock speeds, Raptor Lake packs a serious punch. But I'm uneasy about the power consumption.

I suspect both Raptor Lake and its Alder Lake predecessor were originally intended for Intel's 7nm node rather than 10nm. Consequently, they're both hot and hungry architectures. That's a problem I'm not expecting to disappear when Meteor Lake arrives on 7nm next year. If Alder Lake and Raptor Lake were meant to be on 7nm, Meteor Lake was probably intended for 4nm. It's going to take a while before Intel's production nodes and architectures fully align again.

All of which leaves AMD's RDNA 3 graphics architecture. By the time you read this, AMD will have pulled the wraps off the top few members of the family. I'm not expecting to be as infuriated by RDNA 3 as I was by Nvidia's RTX 40 Series graphics. But if the latest rumors are accurate, even RDNA 3 won't be as thrilling as we'd hoped.

If all that makes for a downbeat read, here's the thing. The RTX 4080 is annoying and Intel messed up Arc. However, there's still some great new technology available for the PC and plenty more to come soon. If you love the PC, it's too easy to get carried away by product launches and road maps. If that's my bad, the immediate future of the PC is far from gloomy. It's just not quite as stellar as I'd hoped.

Six raw 4K panels for breakfast, laced with extract of x86… Jeremy Laird eats and breathes PC technology.

© NVIDIA

DOCTOR

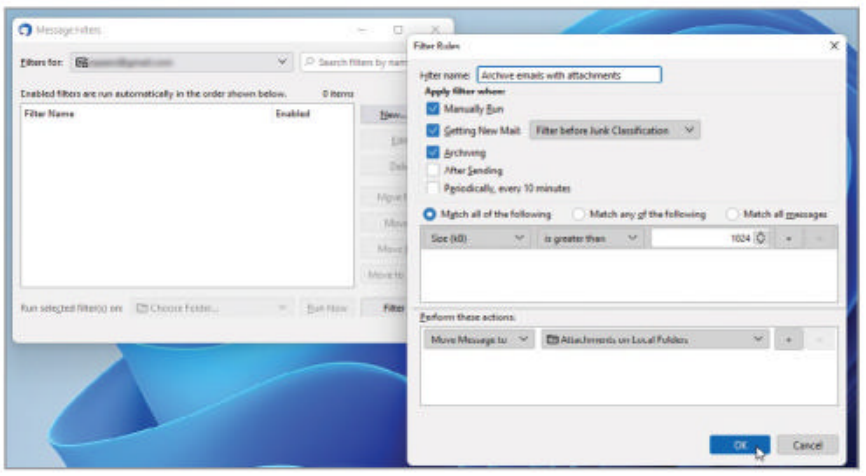
THIS MONTH THE DOCTOR TACKLES...

> Which mesh system?
> Archive emails offline
> Noisy fans

Confusion over mesh

I've got a couple of dead spots in my home network. The obvious solution would appear to be a mesh network, but there's so much choice—even from the same manufacturer sometimes. What sort of things should I be looking for when shopping for a mesh network?

—Joel Dawson



Move old emails offline to free up online space.

THE DOCTOR RESPONDS:

There are many things to consider when looking at mesh networks. If you're looking to futureproof your mesh network, then make sure it supports WiFi 6 as a minimum, and WiFi 6E if you have lots of devices where competing demands for network bandwidth could exacerbate your problems.

WiFi 6 adds an additional 160MHz channel to the 5GHz spectrum, so those devices capable of using WiFi 6 (802.11ax) are moved on to a separate channel away from other 802.11ac (WiFi 5) devices to boost performance and capacity. The major difference between WiFi 6 and WiFi 6E is that the 'E' stands for extended, extending the WiFi 6 channel into the 6GHz band to get an extra 1,200Mbps bandwidth for increased performance and capacity.

WiFi 6E charges a hefty premium (around $150) and with many people still primarily using older WiFi 5 devices, there's little to be gained right now by choosing it over WiFi 6. Other factors come into play, namely the number of bands provided by the router and the maximum advertised speeds.

You'll see routers with listings such as AC2400 or AX4000. The 'AC' or 'AX' identifies them as either WiFi 5 or WiFi 6/6E, while the secondary figure is a theoretical maximum speed offered across all available bands. For example, an AC1750 dual-band router might offer up to 450Mbps on its 2.4GHz channel, and 1,300Mbps on its 5GHz channel.

A tri-band WiFi 6 router can deliver improved performance across three channels, for example, the Asus ZenWiFi XT9 AX7800 router divides its capacity to offer up to 574Mbps over its 2.4GHz channel, 2,402Mbps on the WiFi 5 5GHz channel, and 4,804Mbps on the WiFi 6 5GHz channel. Proving that not all WiFi 6E routers offer superior top speeds, Amazon's new eero Pro 6E only supports up to 5,400Mbps across its three channels: 600Mbps over 2.4GHz, then 2,400Mbps on each of the other channels.

These speeds are all theoretical, of course, which is why it's important to also see what range is offered as, ultimately, your choice of router should come down to whether it delivers decent performance over an extended range as opposed to how theoretically fast it is when you're stood next to the router itself. In recent tests, for example, we found the ZenWiFi XT9 offered faster speeds at range than the eero Pro 6E.

Other things to look out for include a dedicated 'backhaul' channel. Some mesh devices, including some tri-band WiFi 5 systems, allow you to reserve a channel exclusively to channel traffic between the router and satellites to keep the rest of the bandwidth free for your networking needs. Support for this backhaul often helps extend the range too, allowing you to push each satellite that bit further away from the main router. Also, check to see that WPA3 is supported—most support it, but beware of those that don't include a WPA2 fallback option for older devices when it's enabled, such as Google's Nest WiFi.

Finally, before investing in a new mesh network, check to see if your current router supports mesh. Both

© MICROSOFT

↘ submit your questions to: doctor@maximumpc.com

Asus and Synology bake mesh support in to their latest routers, so you may already find yourself halfway to a solution. And if you're only looking to extend your network to one far-flung location way out of range of your router, consider a HomePlug option, such as the Devolo Magic 2 WiFi Next ($185, www.devolo.com) system instead.

Free up email storage

I don't pay for Google One storage and am running out of space on my account, which I use primarily to store emails. Should I move to a provider that has more free storage, such as Yahoo Mail, use an app to strip attachments from emails, or pay for extra storage?

—Jennifer McDowell

THE DOCTOR RESPONDS: Your options are many and varied, and none involve having to switch email account provider. Of course, you could pay for extra storage—Google One's Basic tier costs $19.99 a year for 100GB of free storage, which should be ample. But why pay when you can simply make better use of your existing storage?

One option is to archive older messages offline, freeing up storage without having to make any awkward decisions over what to keep and what to get rid of. The Doc has been using a free tool called MailStore Home to keep his unruly Google email in check for years (see December 2021 issue).

Alternatively, you could switch to accessing your Gmail through Thunderbird (www.thunderbird.net). Once your account is connected, create a filter to move all messages after a specified date into a local folder, which would then delete the online copy to free up space. Click 'Manage message filters', then click New... and set up a match filter including 'Date' and 'is before', then choose to 'Move Message to' a local folder. Alternatively, you could set up a filter using the Size (kB) parameter to move only those messages containing attachments over a certain file size.

Thunderbird also allows you to 'detach' individual attachments from messages. Save the file to your hard drive and it is deleted while the original email remains online. Sadly, there's currently no way to perform this action in bulk—one such add-on, AttachmentExtractor, doesn't work with the latest version of Thunderbird. Consequently, the Doc recommends the archiving route as your best option.

Noisy fan fix

One of the fans on my desktop PC has started to make an incredibly loud whine and I'm not sure what to do to resolve it.

—Wiley S. Sanders

THE DOCTOR RESPONDS: The first thing to do is identify the problematic fan. Is it your CPU, case, GPU, or maybe even your power supply? Once you've identified the culprit, take a closer look. Is the fan clogged with dust or some other obstruction? Try cleaning it using a can of compressed air or a soft brush, then see if that has any effect on noise levels. Also, make sure there's plenty of room for air to circulate around both fan and your PC.

If your fan is rattling or grinding, then it's likely to be coming to the end of its life, so replace it if possible. If looking to replace a case fan, check with the case manufacturer or measure it carefully (including any screw holes) before replacing it.

CPU fans are also straightforward to replace—make sure you choose the right fan for your CPU model as well as its make, and if you're looking for a bigger fan, make sure there's enough space in your case to accommodate its larger footprint. Once your new fan arrives, run your PC for a while to heat up the CPU and soften the thermal paste connecting it to the heatsink.

Then, carefully remove the old fan before cleaning the CPU die to remove any leftover thermal paste using 91 percent proof alcohol (72 percent would be adequate) and lint-free paper. Some new fans come with thermal paste pre-applied, while others may require you to apply this yourself, so check online videos to ensure you use the right amount for maximum heat transference.

GPU fans can be trickier to replace. If your card is still under warranty, see if the manufacturer will offer a free replacement. Otherwise, you should first verify the fans are removable—many, but not all, are. They may be attached via clips or small screws to a passive heat sink (some may be obscured by stickers), and you should also make a note of the power connector and where it goes on the card.

Even if the fan can be removed, you should source a replacement before proceeding. You will need to search for 'fan' plus your video card make and model to see what's out there.

Finally, the trickiest fan to replace is that on a PSU. You'll need to open up the PSU to identify what the current fan is and whether it's replaceable, then repeat the process when the new fan arrives to actually swap them out. Given the potential for giving yourself a nasty (or even lethal) electric shock, the Doc is wary of recommending such an approach—instead, replace the PSU itself.

Asus's ZenWiFi XT9 offers a great base for a mesh system.

© ASUS

File Explorer freeze

Something odd is happening in Windows: I can drag, drop and double-click files as normal, but as soon as I attempt to right-click a file or folder File Explorer becomes unresponsive. How do I fix it?

—William Erickson

THE DOCTOR RESPONDS: This is usually linked to a shell extension, added by a third-party program into the context menu to provide access to that application. Identifying it is the hardest part, so install ShellExView, free (www.nirsoft.net/utils/shexview.html).

Once installed, launch the program and choose 'Options → Filter by Extension Type'. Click Context Menu so it's the only highlighted entry and hit OK. Now, click the Company column header to the right of Product Name to sort the entries, making it easier to group the non-Microsoft entries together—all are marked in pink.

Hold Shift as you click on the first and last pink entry to select them all, right-clicking the selection and choosing 'Disable Selected Items', then clicking Yes when prompted. Now choose Options → Restart Explorer (again, click Yes when prompted). Try right-clicking now—if the problem goes away, you know it's one of the entries you've disabled.

Now re-enable each entry one at a time, then restart Explorer, until the problem reappears. Once you've identified the culprit, leave its shell extension disabled, remove the program or troubleshoot further using its website.

8K GAMING MONSTER

A gaming PC powered by top-end Intel and Nvidia processors? After two years of inflated prices, chip shortages, and slow progress, next-gen is here, as *Guy Cocker* discovers

THIS IS THE PC we've been waiting all year to build. After months of leaks and rumors about Intel's 13th-generation Raptor Lake CPUs and Nvidia's 40-series Ada Lovelace GPUs, they have both arrived at once. Things were looking good when the RTX 4090 just made it in time for us to review in the last issue of Maximum PC, landing a much coveted 'Kick Ass' award in the process. This issue, we have the Intel Core i9-13900K (reviewed in full on page 74), which—spoiler alert—is also pretty impressive.

There will no doubt be faster CPUs coming soon, and the 4090Ti in a year or so but, right now, these are the best raw materials we have. As such, our build errs towards the premium and the luxurious, using a brand new, high-end Z790 motherboard. That, in turn, necessitates the use of DDR5 RAM. We've also gone with an MSI GPU that boasts slightly higher clock speeds than the Founders Edition of the RTX 4090, and chosen NZXT's premium case and cooler. The only thing we didn't max out on is storage—we'd loved to have used one of the first PCIe 5.0 SSD drives but, alas, they weren't available at the time of building. The good news is this system will be ready for the upgrade as soon as they do become available.

So, is this the gaming system to end all gaming systems? Is it worth upgrading from previous-generation CPUs or GPUs? And is it worth the relatively high asking price? We'll attempt to answer all these questions and more in a feature that will tell you all you need to know about next-gen PC gaming. So get that screwdriver ready, as we build 2022's ultimate gaming PC.

INGREDIENTS

PART		PRICE
CPU	Intel Core i9-13900K	$660
GPU	MSI GeForce RTX 4090 Gaming X Trio	$1,649
RAM	Corsair Vengeance 32 GB (2x 16 GB) DDR5-5200 CL40	$160
Mobo	Asus ROG Maximus Z790 Hero	$630
Storage	PNY XLR8 CS3140 1TB	$100
Case	NZXT H7 Elite	$200
PSU	NZXT C850 80+ Gold	$130
CPU Cooler	NZXT Kraken X73 RGB AIO	$200
OS	Windows 11 Home	$20
TOTAL		**$3,749**

PRICES CORRECT AT TIME OF PRINTING

NZXT
msi
GAMING
TRIO

WHAT'S IN THE BOX?

CPU

INTEL CORE I9-13900K

Last month, we reviewed the first 'next-gen' CPU out of the gate, the AMD Ryzen 9 7950X. While it was AMD's brand new top-tier processor, it didn't manage to beat the equivalent Intel processor, the i9-12900K, in many of our benchmarks. So that made us even more eager to see how well Intel's follow-up, the i9-13900K, would do in terms of performance. You can read the full review on page 74, but on the specs level, there's a jump from 16 to 24 cores (with the efficiency cores doubling from eight to 16), thread count increasing a third from 24 to 32, and a boost clock jump to 5.8GHz from 5.2GHz.

The L2 cache has also gone up significantly from 14MB to 32MB, while base TDP remains the same at 125W, with a slightly higher boost TDP of 253W. While our CPU price is based on the launch RRP when demand is naturally high, if you're able to wait, we expect the price to drop below $600 in the coming months. It's also worth noting that you don't have to invest in a Z790 board—Intel's 13th-generation chips work fine on Z690 boards using either DDR5 or DDR4 RAM. See our performance comparison on page 28.

• *$660* • *www.intel.com*

GPU

MSI GEFORCE RTX 4090 GAMING X TRIO

Now for the star of the show. We were effusive with our praise of the RTX 4090 when we ran it through our labs last month. Now available to buy, anyone who has the money to be on the cutting edge of gaming will no doubt either be lusting after it or, if they're lucky, enjoying it in their gaming PC. While we reviewed Nvidia's Founders Edition card, this time we were offered MSI's Gaming X Trio, which on paper only costs $50 more than the FE, although good luck finding it for that price right now.

It's a huge and heavy card, measuring 34x14cm and weighing 2.2kg, that requires an included support bracket screwing into the case to ease the strain on your motherboard. The MSI card boasts a small boost clock of 2,595MHz, which is 75Hz more than the FE board, plus a 16-pin power adapter needing three PCIe power cables from the PSU.

• *$1,649* • *www.msi.com*

Motherboard

ASUS ROG MAXIMUS Z790 HERO

There are two motherboards you can use for Intel's 13th-generation processors, the Z690 or the Z790. The Z790 is the latest and greatest, released alongside Raptor Lake and supporting more PCIe 4.0 lanes and faster DDR5 RAM (up to 5600MHz) than its predecessor. What do more PCIe 4.0 lanes offer? Well, more high-bandwidth M.2 slots—there's a ridiculous total of five on this motherboard plus additional Thunderbolt 4 controllers.

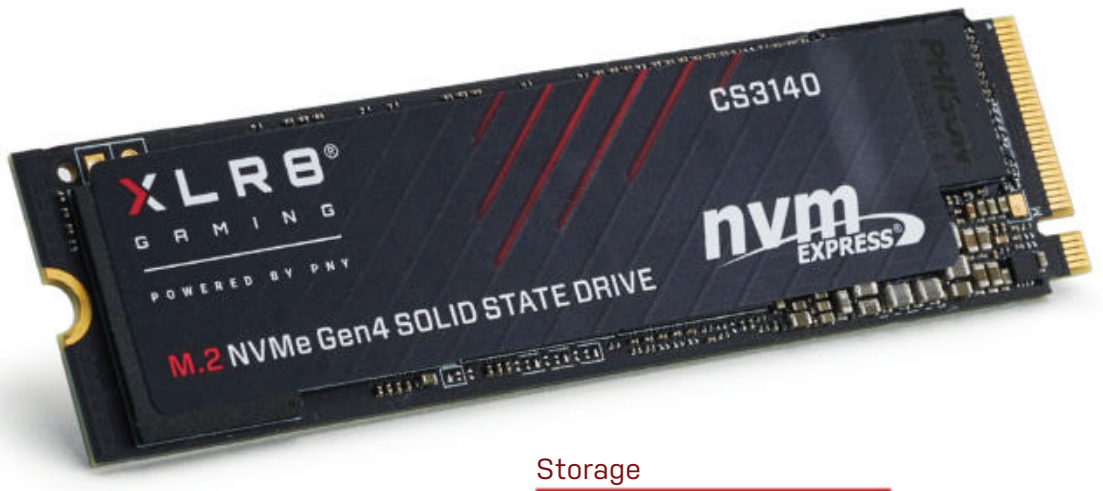
While we've taken advantage of faster 5200MHz RAM on this build, which wouldn't work on a Z690 board, builders should look hard at whether a Z790 board is worth the extra expense at this stage. This Asus ROG Maximus Z790 Hero is a fantastic board—it looks great, has lots of I/O ports, and allows you to max out this top-of-the-line system. However, it costs nearly as much as the CPU itself. • *$630* • *www.asus.com*

RAM

CORSAIR VENGEANCE 32 GB *(2x 16 GB)* DDR5-5200 CL40

We couldn't quite believe our eyes when pricing up this system and seeing how cheap this DDR5 RAM from Corsair was. DDR5 prices have dropped dramatically this year, and while they still aren't at DDR4 levels, where an equivalent kit is $100, it makes the jump up much less painful for those adopting the next-gen.

What's notable about these Corsair sticks is that they're clocked at 5,200MHz, which doesn't max out the motherboard but does at least take advantage of the latest Z790 hardware. They also look sleek in white, although they're also available in Black and RGB if you fancy a different look. The RAM is Intel XMP-ready, meaning it's just one click to optimize them in the system BIOS, and they have a lifetime warranty for extra peace of mind.
• *$160* • *www.corsair.com*



Storage

PNY XLR8 CS3140 1TB

Another nice surprise alongside DDR5 RAM is the rapidly falling prices of PCIe 4.0 SSDs. For $100, you can get this PNY XLR8 SSD promising 7,500MB/s read and 5,650MB/s write speeds with a 1TB capacity, which is more than enough to run an operating system, some games, and your work portfolio. Hardcore gamers will probably want to spring for the 2TB model for $200 to store more games, and/or invest in a mechanical hard drive if their Steam collection demands it.

Like many M.2 drives, this model can also be purchased with a heatsink, but we don't need one on this motherboard. The drive also includes a five-year warranty. • *$100* • *www.pny.com*

Case

NZXT H7 ELITE

Our writer Sam has been reviewing all of NZXT's H7 lineup over the past three issues, including the standard H7, H7 Flow, and the H7 Elite. While overall he recommends the cheaper Flow because of its efficient cooling, the Elite model at the top of the tree has plenty of premium features without being extravagantly expensive.

In Sam's review (October issue, page 78), he notes the three premium RGB fans pre-fitted to the front, the toolless access across all of the panels, and the excellent cable management to keep things neat and tidy inside. The pre-fitted RGB controller can support lots more fans and coolers, plus there's loads of room inside for big components such as the ATX motherboard and MSI GeForce RTX 4090 Gaming X Trio GPU.
• *$200* • *www.nzxt.com*

PSU

NZXT C850 80+ GOLD

There's a lot to like about NZXT's power supply—it's fully modular, meaning you can keep the inside of your case neat and tidy, there's a button on the rear to spin down the fans for quieter semi-passive operation, and it keeps cool at 47°C under load. It also feels reassuringly well made, thanks to quality components based on the Seasonic Focus Plus Gold platform, as well as being nice and compact at only 14cm deep. The ten-year warranty is also nice to have and lasts longer than most people would reasonably expect to use it for. However, if you plan on overclocking the GPU or CPU even a little, we would highly recommend going for a 1000W PSU—the PCPartPicker website warned us that we were already at 823W with this system out of the box.

• *$130* • *www.nzxt.com*

CPU Cooler

NZXT KRAKEN X73 RGB AIO

When it comes to quality and design, we do like NZXT's gear. You could save some money by buying an AIO cooler from another manufacturer, using a smaller 260mm radiator, or dropping the RGB element of the package, but when you're building a 4K gaming rig, chances are you're looking for good quality, dependable components.

While we're not planning on overclocking this particular build, going for a good cooler like this will allow us extra headroom to push the CPU harder in future. We like the style of the infinity mirror display on the cooler itself, with white circles going on forever, plus a rotatable NZXT logo to fit any orientation.

• *$200* • *www.nzxt.com*

8K FOREVER

BUILD YOURSELF THE BEST GAMING PC OF 2022

LENGTH OF TIME: **2-3 HOURS**
LEVEL OF DIFFICULTY: **MEDIUM**

3 GOING TO THE TIPPITY TOP

PCIE DEVICES SUCH AS M.2 SSDS nearly always go in the uppermost slots available, as these usually offer the fastest speeds. Not on this board, though. The Asus ROG Maximus Z790 Hero comes with a 'Hyper M.2 Card' expansion board which is the only way you can take advantage of PCIe 5.0 drives, as the three M.2 slots on the board are PCIe 4.0. No problem though, as that's what we're using here. We remove the reassuringly enormous heatsink below the CPU by unscrewing two small screws, take the blue plastic off both sides of the thermal pads, insert the PNY SSD at a 30° angle, and use the plastic retention clip to secure the drive in place. Finally, we screw the heatsink back on and that's the storage sorted.

4 MOUNTING MADNESS

WE CAN FEEL you silently judging us here as we now drop the motherboard into the case. "What about the RAM sticks?" you may ask. Well, worry not, as this is intentional—see step 9 to learn why we skipped that for now. To get the motherboard in place, we lay the case on its side, gently lower the mobo in, line the I/O ports up with the rear of the case, and locate the eight screws required to lock the motherboard in place from its box. It's one of the easiest parts of the build, but it's here we start to appreciate just how good this case is for cable management. The case has holes in all the right places, which should keep everything neat and tidy.

1 BOXING CLEVER

IT'S BEEN FIVE ISSUES since I did my previous build for *Maximum PC*. In that time, I've read enough guides from our writer Sam to know it's always a good idea to kick things off by getting the case as empty and accessible as possible. As the NZXT H7 Elite is a mid-tower case, there's plenty of room to work with without making the case ridiculously big, like the massive Corsair 7000D Airflow from our October issue. We removed the side, front, and top panels from the case, all of which can be detached without tools, took out the three pre-installed 140mm F Series RGB Fans that come with the case, and removed the mechanical hard drive cage from the base of the machine, as we won't be using it.

2 PROCESSING THE INFORMATION

WITH THE CASE EXPOSED and ready to be filled, we next turn to the motherboard, which we populate with components before securing it into the case. We like to use the motherboard's box as a base when building, as it's the right size and protects the underside of the board from damage and slips. After removing the board from the anti-static bag, take off any protective plastic film (or leave this to the end if you're worried about scratches). Next, pop up the retention arm for the CPU, place the processor so the text is the right way up, and push the arm back down to lock it in. Any plastic coverings will pop off once the chip is in place.

5 THE KRAKEN AWAKENS

NEXT UP, it's time to start thinking about how we're going to keep this machine cool. Having already taken the three 140mm front case fans out of the H7 Elite, we replaced them with the three 120mm fans and the 360mm radiator that come with the Kraken X73 RGB AIO cooler. Mounting them in the case is simple—just use the longer screws that come with the cooler to go through the case, fans, and radiator to hold them all in place. We particularly like this cooler because the fans can be daisy-chained together—each fan has an 'in' and an 'out' socket that makes cable management both easy and tidy. The top fan cable then simply goes into the case's pre-installed fan controller.

6 TO INFINITY AND BEYOND

WITH THE FANS and radiator in place, it's time to get the cooler mounted onto the CPU. This is the first tricky part of the build, so here, it pays to take your time. The first step is to get the LGA1700 mounting bracket from the box—this is included on the Kraken X73, but additional ones can be requested from NZXT if required. Push the mounting holes as far as they go outwards, peel off the adhesive, and attach it to the back of the motherboard. Flip the case over, apply a small amount of thermal paste (you will need to buy this separately) to the top of the CPU, then use the LGA1700 mounting screws to secure the cooler in place, being careful not to over-tighten. Remember to rotate the NZXT logo if need be, connect the fan header to CPU_FAN or AIO_PUMP on the motherboard, and the micro USB cable to a USB 2.0 header on the motherboard so the lighting can be controlled by NZXT CAM software in Windows.

7 GPU TEARDOWN

NEXT UP, we opted to use two of the leftover case fans at the top of the case for the exhaust—after all, this performance PC could be getting pretty toasty. The top of the case supports two 140mm fans or three 120mm fans, so we put two of the three bigger fans that we have available into position. Looking back, we perhaps should have swapped out that rear non-RGB fan with the spare RGB fan we had left for a more uniform look. And, if we were doing this build again, we'd probably keep the three front 140mm fans where they were by default, put the radiator on top, and properly utilized all the fans we had. There's no right answer to where you should mount your radiator, of course, with benefits and drawbacks to both a front and top location, but we'll admit it probably would have made sense to go with a top-mount here.

8 TINY BUT MIGHTY

OK, WE GET IT, it's starting to look as though we raided the stock cupboard at NZXT and grabbed everything we could find. But looking at a product like this C850 80+ Gold PSU, it's easy to recommend. It's absolutely tiny, which makes fitting it into this case a breeze, it has a button on the back for silent operation, and the modular design means it's a doddle to set up.

In our build, we needed a motherboard cable, two CPU cables, a SATA power cable for the case and cooler, and three PCIe cables for the MSI graphics card. The Nvidia Founders Edition needs four power cables, and remember, each cable needs its own separate connection to the PSU. Don't go using two ends from one cable, as it won't provide the requisite power. Nobody wants a broken 4090.

11 PREMIUM CABLE

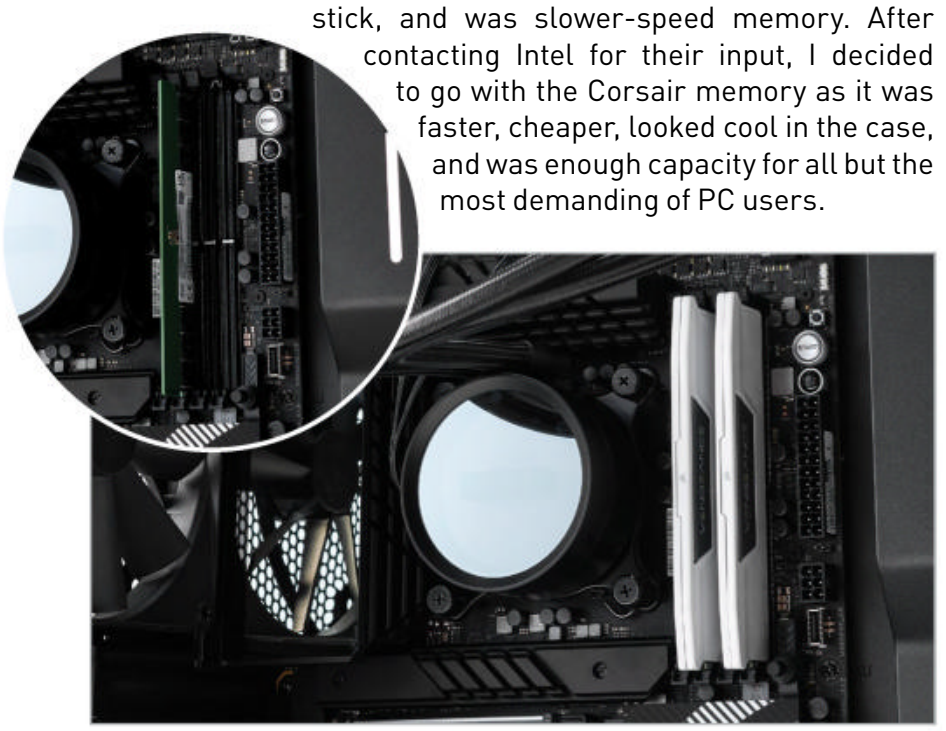
NOW IT'S TIME to get all of the power cables running from the power supply to the motherboard and various components. Most of this was relatively straightforward, and while the cables provided by NZXT look basic, they're long and nimble enough to weave around the case without too much effort. As mentioned back in step 4, the H7 Elite is a great case if you like easy cable management, as the holes are positioned and angled perfectly for a modern build, including in the base for the three power cables needed for the RTX 4090. Our photographer's nimble fingers were needed to fit the FPANEL, USB, and HD AUDIO cables to the bottom of the motherboard. When you're building, you might want to do this before fitting the GPU support bracket.

12 CABLE TIDY

WE'VE ARRIVED AT every PC builder's least favorite part of the building process—cable management. To be fair, it isn't as horrible here as it was with my previous build, the tiny NZXT H1 console-style case, because this case has plenty of space and some great cable management. All of the fan cables are easy to keep neat and tidy in the NZXT fan controller pictured, while it's a simple job to keep everything channeled using NZXT's included velcro straps. The trickiest was the USB cable that runs from the cooler to the motherboard to control its lighting—the cable is too tight to feed into any of the cable ties, so it has to just sit loosely on the rear of the motherboard. On the plus side, as we took the HDD caddy out of the bottom of the case, there's loads of room to keep power cables tucked out of the way.

9 DECISIONS, DECISIONS

AS WE MENTIONED in step 4, we would normally have put the RAM in earlier, but this time we waited. We found a few different sets of RAM in the *Maximum PC* labs and wanted to make the right decision on what to use. The set that first caught our eye was two sticks of SK Hynix 32GB DDR5 4800MHz (see inset image), giving 64GB overall. There were also two sticks of 16GB Corsair Vengeance DDR5 5200MHz for 32GB total (main image). Counting against the SK Hynix was that it looked horrible, cost $200 per stick, and was slower-speed memory. After contacting Intel for their input, I decided to go with the Corsair memory as it was faster, cheaper, looked cool in the case, and was enough capacity for all but the most demanding of PC users.

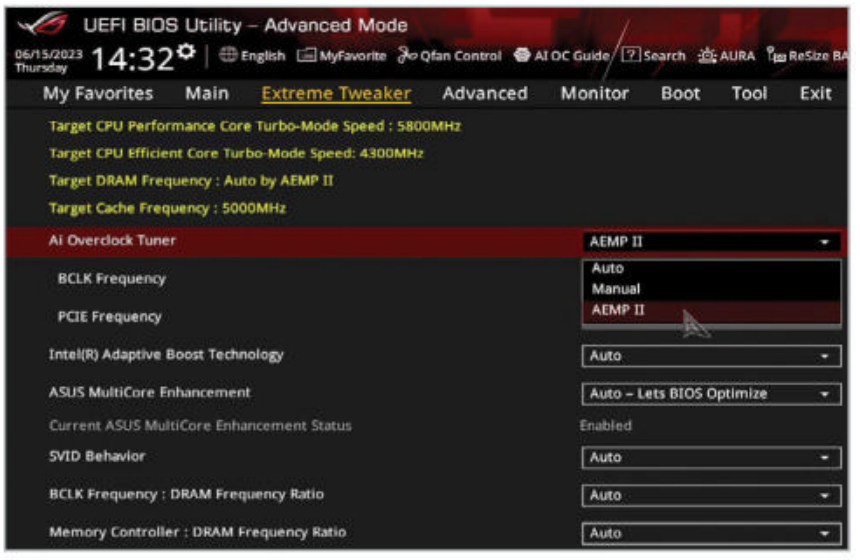


10 FEEL THE (GE)FORCE

BY NOW, I'M SURE most of you have heard about the size and the weight of the RTX 4090 graphics card, but still, nothing quite prepares you for its ungainly proportions. Everything about this card is ridiculous, but it's the mounting bracket that's the really frustrating element. Asus boasts that its mobo is built "to bear the brunt of massive graphics cards" but MSI's 2kg beast laughs at such assertions and requires its included bracket to support the weight. The bracket needs three screws to secure, is fiddly to fit while retaining the case's slot brackets, and blocks off access to the bottom of the motherboard, making it extremely complicated to fit the cables afterwards, or other PCIe devices down the line.

13 STAYING UP TO DATE

THAT'S IT FOR THE BUILD. You can pop the panels back onto the case, plug the power cable into the PSU and cross your fingers as you power the thing on. We plugged an HDMI cable into the motherboard in order to get the computer to display anything on our monitor, and when we did, the Asus motherboard informed us it had recognized a new CPU and told us to hit F1 to set up the BIOS. At this stage, you can just tell the machine to Load Optimized Defaults, then Save and Exit to get ready to install Windows. But wait! Before you do that, on another computer, head to Asus's website and download the latest BIOS to a USB stick. Hit the DEL key when booting up and use the BIOS's update function to upgrade, which should take a few minutes.



© ASUS, MICROSOFT

14 HARDWARE WITHOUT SOFTWARE

ON ANOTHER COMPUTER, search online for 'Create Windows Installation Media', and use a USB stick to create a bootable Windows installer. This should take around 10 minutes to create the media and another 20-30 minutes to install, so take a well-earned coffee break. On this machine, we had to restart the installation process and install a network driver to continue. Again, put the file on a USB stick using Asus's website and you'll need either a Windows 11 license key or your Microsoft login to finish the installation. Once in, go to Windows Update to get all the latest updates. On our build, a notification appeared to remind us to download Asus's Armoury Crate, which manages all the chipset and other important drivers. We'd suggest doing this too.

GAMING PARADISE?

IF YOU'VE SEEN OUR RTX 4090 REVIEW, you won't need me to tell you that this card is a gaming powerhouse, offering a genuine leap forward over the previous generation in terms of raw performance. In the benchmarks, I used our 4K 'Ultra' machine from our July 2022 issue as a Zero Point comparison. That machine cost roughly the same price ($3,600) and used the top-end components available then, including an RTX 3090 graphics card, AMD Ryzen 9 5950X CPU, and 32GB of DDR4 3200MHz RAM. All I can say is, what a difference six months makes. At 4K, we get a doubling of performance in *Metro Exodus* RTX, close to double in the 3DMark Fire Strike Ultra score, and even at the lowest improvement in *Cyberpunk 2077*, we still see a 63 percent gain. CPU performance offers less of a leap forward, with a 33 percent boost to single-core tasks and a 24 percent increase to multi-core. That's still pretty impressive, though.

Those benchmarks only test core computational performance, they don't take into account the benefits of DLSS 3 upscaling, as we turn such performance enhancers off in our testing. With DLSS 3 being exclusive to the RTX 40-series of GPUs, there are undoubtedly more performance benefits to be gained, which is where Nvidia gets its '2x-3x' performance claims over the 30-series in its marketing. It's a bit early to declare whether it's worth upgrading to gain access to DLSS 3 because, at the time of writing, showpieces for the tech such as Portal RTX haven't been released yet. For more on DLSS 3 though, and the best games to test on your new 4090-based system, turn to page 30.

As we've now had both the Intel Core i9-13900K and AMD Ryzen 9 7950X through our labs, we can see that Intel takes the lead in single-core performance, while Ryzen wins for multi-core. If you're yet to decide whether to go for Raptor Lake or Zen 4, this may be something to think about. We'd give the overall win to Intel, its chip is $40 cheaper and more versatile in terms of working with older platforms and RAM, which could save you quite a bit of money. Then there's the fantastic Core i5-12600K (see page 76), which offers a good chunk of the i9's performance for less money. Then there's the issue of whether you need DDR5, which we explore in our comparison on page 28.

Overall though, do we recommend building an RTX 4090-based system? On a physical level, we found the installation tricky, with a fiddly mounting bracket, a heavy card, and an annoying number of power cables to be fed through the system. There's also the issue of cost at $1,599, which is $100 more than the RTX 3090 launch price, but $400 less than the 3090 Ti launch price in March. Still, given the current cost of living and sense of impending economic doom, the 4090 feels like more of a luxury than ever.

But if you're a serious gamer who's going to put in hours of playtime on this thing, the RTX 4090 is actually easy to justify. Like the Nvidia Titan X back in 2015, there's something glorious about being able to play any game, whack the settings up to max and not worry about getting playable frame rates. The difference is that the RTX 4090 will even do that at 4K, which is genuinely something to marvel at if you have such a monitor or television.

1 The ROG Maximus Z790 Hero is certainly futureproofed, with DDR5 RAM, PCIe 5.0 support and five M.2 SSD slots.

2 This 2kg beast of a GPU takes up a large chunk of space in this roomy case, and needs the included bracket for support.

3 This GPU also requires three separate PCIe cables to power it. Luckily, this case has a hole in the base to feed them through.

4 We placed the NZXT radiator at the front, but as we noted in step 7, putting it up top would have allowed us to make use all our RGB fans.

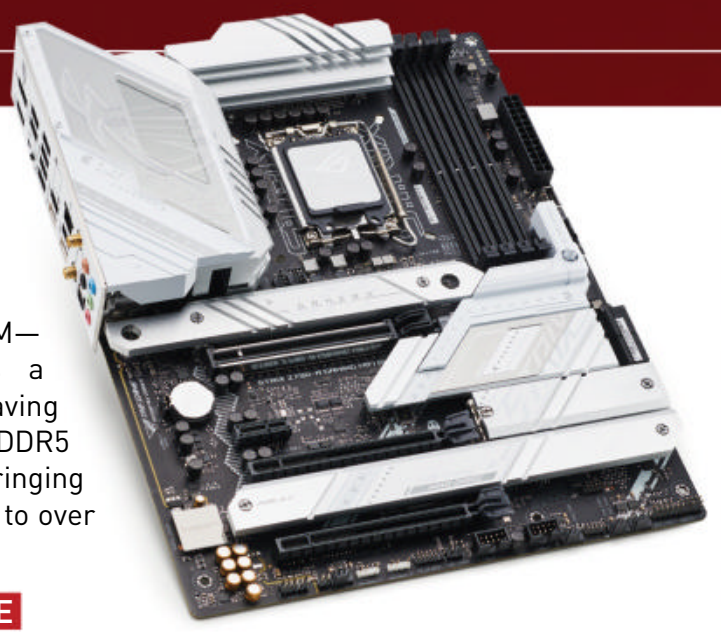
BENCHMARKS

	ZERO POINT	
Cinebench R23 Single-Core (Index)	1,691	2,247 (33%)
Cinebench R23 Multi-Core (Index)	28,692	35,457 (24%)
CrystalDisk QD32 Sequential Read (MB/s)	7,089	7,057 (-0.5%)
CrystalDisk QD32 Sequential Write (MB/s)	6,743	5,303 (-21%)
3DMark Fire Strike Ultra (Index)	12,785	24,528 (92%)
Cyberpunk 2077 (fps)	48	78 (63%)
Cyberpunk 2077 RTX (fps)	23	43 (87%)
Metro Exodus (fps)	77	140 (82%)
Metro Exodus RTX (fps)	52	105 (101%)
Total War: Three Kingdoms (fps)	61	100 (64%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of the "Ultra" 4K build from our July 2022 issue, featuring an AMD Ryzen 9 5950X, Zotac Gaming GeForce RTX 3090 AMP Extreme Holo 24GB, MSI MPG X570S Carbon Max Wi-Fi, 32GB of G.Skill TridentZ DDR4-3200, and 2TB MSI Spatium M480 M.2 SSD. All games tested at 4K 'Ultra' graphics presets with DLSS and V-sync turned off and XMP for RAM speed turned on. No manual CPU overclocking.

DDR5 VS. DDR4



WHILE WE INTENTIONALLY BUILT this PC using all the latest components with the aim of seeing what a state-of-the-art system is capable of, we were also aware that real-world builders may not be able to afford to go quite as far as we did. After all, if you've got your heart set on an RTX 4090 and you're dropping at least $1,600 on it, no one could blame you for wanting to save a bit of money on the other components. Or maybe even reuse some of the components you already own.

Our writer Sam and I broached this subject when discussing this build. Would it be useful to look at comparing this system to one using a previous generation Z690 board, or perhaps a Z790 board using older DDR4 memory? Based on what we knew, we thought a Z690 DDR5 board would offer similar performance, but there might be more merit to comparing DDR4 and DDR5-based systems. In the end, the situation was resolved with the help of Intel, who kindly provided us with an Asus ROG Strix Z790-A Gaming WiFi D4 (pictured above right), which uses DDR4 memory. We swapped the ROG Strix out for the ROG Maximus Z790 Hero as soon as we were finished testing, replacing the memory with PNY XLR8 Gaming Rev RGB 32GB (2x 16GB) 3200MHz DDR4 RAM, but keeping all other components the same.

The ROG Strix board comes in at $380, saving $250 alone over the $630 ASUS ROG Maximus Z790 Hero. The cheaper board lacks the aforementioned DDR5 RAM support and also doesn't offer PCIe 5.0 storage, but with those kinds of savings, a lot of people probably won't mind. Then there's the cost of the PNY XLR8 Gaming RAM—at $100, that's a 38 percent saving over the Corsair DDR5 equivalent, bringing the total savings to over $300.

PERFORMANCE

As you can see from the benchmark table, the big news between DDR4 and DDR5 performance using Intel's Raptor Lake chip is that there's really no difference at all. Indeed, the only test from our benchmark suite that falls outside the margin of error territory is the Cinebench R23 Multi-Core (Index), where the older memory resulted in a score 9 percent below that of DDR5.

That difference might matter to creatives who run intensive encoding tasks, but for most it's not really worth paying a premium for. Of course, it's not an entirely fair comparison—we pitted a cheaper DDR4 board against a high-end DDR5 board, and you could find cheaper or more expensive boards in either configuration. But based on this particular test, you don't get a huge CPU performance uplift by spending more on your motherboard and RAM.

If your priority is gaming, then the difference between a DDR4 and a DDR5 board is negligible, and we'd recommend saving some money here. Of course, this won't be the same in every

BENCHMARKS

	DDR5	DDR4
Cinebench R23 Single-Core (Index)	2,247	2,171 (-3%)
Cinebench R23 Multi-Core (Index)	35,457	32,164 (-9%)
CrystalDisk QD32 Sequential Read (MB/s)	7,057	7,022 (-0.5%)
CrystalDisk QD32 Sequential Write (MB/s)	5,303	5,295 (-0.2%)
3DMark Fire Strike Ultra (Index)	24,528	24,519 (0%)
Cyberpunk 2077 (fps)	78	77 (-1%)
Cyberpunk 2077 RTX (fps)	43	43 (0%)
Metro Exodus (fps)	140	140 (0%)
Metro Exodus RTX (fps)	105	104 (-1%)
Total War: Three Kingdoms (fps)	100	101 (1%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our DDR5 system uses an Asus ROG Maximus Z790 motherboard and Corsair Vengeance 32 GB (2 x 16 GB) DDR5-5200 CL40 RAM. Our DDR4 system uses an ASUS ROG Strix Z790-A Gaming WiFi D4 motherboard and PNY XLR8 Gaming Rev RGB 32GB (2 x 16GB) 3200MHz DDR4 RAM. All other components remain the same between the two builds.

game—some media outlets have reported up to 20 percent gains in a selection of titles when using DDR5, such as *Far Cry 6* and *Bright Memory*—and other future games may be better optimized to take advantage of DDR5's higher speeds. We also expect DDR5 prices to continue to fall in price, and we may even get to the stage in the near future where DDR5 reaches parity with DDR4. But if you already have DDR4 memory, then there's a good case to be made for sticking with it for now, as our figures show.

STABILITY

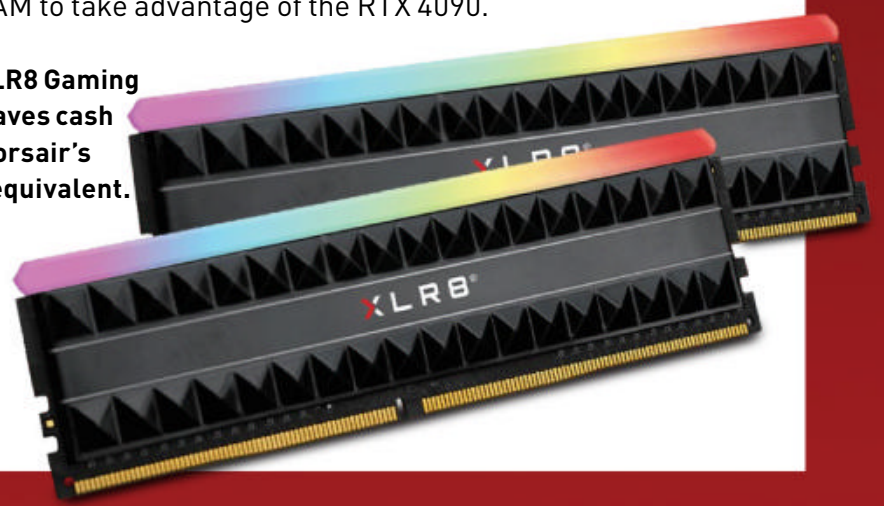
It's worth mentioning that we encountered plenty of Windows issues when building the DDR5 model that didn't affect the DDR4 model. Windows 11 was incredibly temperamental when we first put the cover build together, with Blue screens of death, random lockups, and a refusal from Windows to update to the latest 22H2 update being just some of the issues we faced. We saw other early builders on Twitter complaining about the same problems. We recommend keeping the BIOS and Windows up to date, checking your power cable connections, and maybe even looking into a 1000W PSU.

Meanwhile, the Asus ROG Strix Z790-A Gaming WiFi D4 was much more stable and didn't suffer from these issues, even though we were using the same components apart from motherboard and RAM. It could just be that we were unlucky, but it's something to bear in mind if you're planning on building a similarly cutting-edge system using Intel and Nvidia's latest chips. We were building in the week that the new Z790 motherboards and Intel chips were released, so hopefully, these issues will be ironed out in the coming weeks. Hopefully by the time you read this, most of these stability issues will have been addressed.

CONCLUSION

If you're investing in a top-of-the-line CPU and GPU, it's tempting to give your whole system an overhaul to give those components the best chance to perform at their peak. However, our tests show that, at least for now, it's not worth the extra outlay for gamers, while creatives shouldn't expect massive gains either. If you're an Intel 12th-generation Alder Lake user who has a Z690 board that you could just drop the 13th-gen Raptor Lake chip into, then we'd recommend you do that. That way, you can still upgrade to a new motherboard and RAM if you feel the need to down the line.

If you're a video editor who needs the fastest multi-thread performance, you might be able to justify the cost of a DDR5 upgrade to eke out the extra performance. You might also wish to take advantage of the performance boost promised by PCIe 5.0 SSDs when they launch, in which case you'll need a newer board. But don't expect the first of these SSD drives to double the 7,000MB/s read performance of PCIe 4.0 drives. For gamers though, this is good news—you don't need the latest motherboards and RAM to take advantage of the RTX 4090.



PNY XLR8 Gaming RAM saves cash over Corsair's DDR5 equivalent.

© PNY

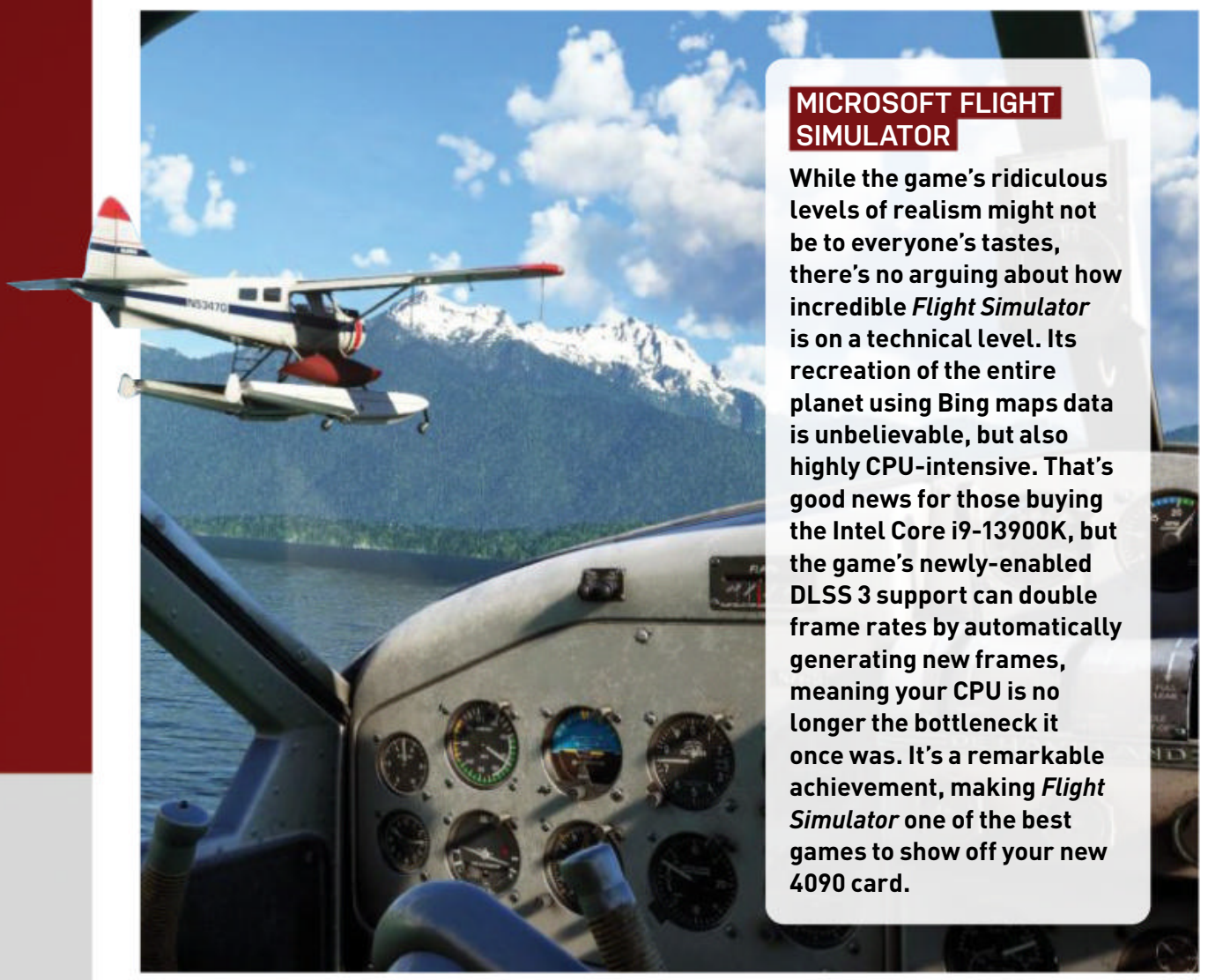
RTX 4090: WHAT TO TRY FIRST

THE BEST GAMES AND HARDWARE TO SHOW OFF YOUR NEW GPU

YOU KNOW the feeling—you've got a shiny new toy and can't wait to see what it can do. In the case of the RTX 4090, that means throwing the most demanding games at it, trying out the first DLSS 3 titles, and pairing it with a 4K monitor. If you followed our guide to building your high-end gaming system, that's the hard part done, now it's about sitting back, making the most of that $1,600 you just dropped on a GPU, and enjoying the best gaming experiences on the planet. So get that Steam wishlist at the ready, here's what you need to do first.

CYBERPUNK 2077

Like it or loathe it, *Cyberpunk* is still the 2022 barometer of PC gaming and our modern-day version of "will it run *Crysis*?". To its credit, developer CD Projekt RED has spent the last two years fixing problems and getting the game to where it should have been at launch. The RTX 4090 is the first card that can run the game at 4K with ray tracing at a playable framerate (43fps in our tests, nearly double what the RTX 3090 could manage). Using DLSS 3, that frame rate triples to over 130fps—it's glorious to behold.



MICROSOFT FLIGHT SIMULATOR

While the game's ridiculous levels of realism might not be to everyone's tastes, there's no arguing about how incredible *Flight Simulator* is on a technical level. Its recreation of the entire planet using Bing maps data is unbelievable, but also highly CPU-intensive. That's good news for those buying the Intel Core i9-13900K, but the game's newly-enabled DLSS 3 support can double frame rates by automatically generating new frames, meaning your CPU is no longer the bottleneck it once was. It's a remarkable achievement, making *Flight Simulator* one of the best games to show off your new 4090 card.

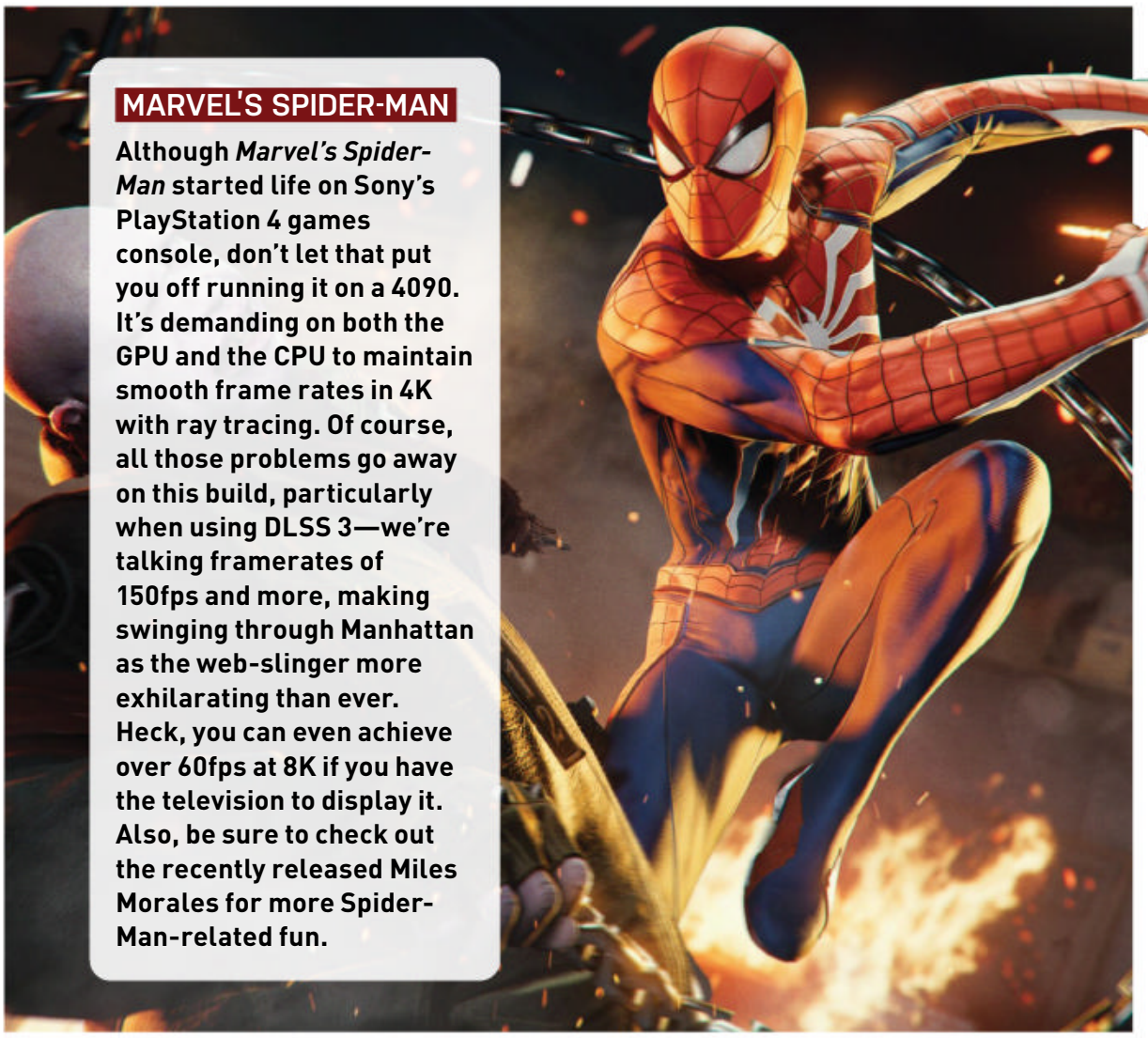
PORTAL WITH RTX

The demo Nvidia used to show off its latest tech during the RTX 4090 announcement was *Portal*, a free upgrade for owners of the game. It may be 15 years old, but it's still one of the best games made. Nvidia's in-house Lightspeed Studios has used RTX Remix to give it a visual makeover with full ray tracing, hi-res textures, and enhanced high-poly models. The result is superb and is available to all RTX card owners—40-series owners can take advantage of DLSS 3 for higher frame rates.

© CD PROJEKT, MICROSOFT, VALVE CORPORATION

A PLAGUE TALE: REQUIEM

One of the first games to take advantage of Nvidia's new DLSS 3 tech, *A Plague Tale: Requiem* is a phenomenal action-adventure survival horror game. Running on an RTX 4090, the game is a brilliant showcase for the power of Nvidia's Ada Lovelace platform. By enabling DLSS 3, you can max out the settings and run the game at 8K with a solid 60fps performance. While few will be able to do it, those who can will experience the future of gaming, today.



MARVEL'S SPIDER-MAN

Although *Marvel's Spider-Man* started life on Sony's PlayStation 4 games console, don't let that put you off running it on a 4090. It's demanding on both the GPU and the CPU to maintain smooth frame rates in 4K with ray tracing. Of course, all those problems go away on this build, particularly when using DLSS 3—we're talking framerates of 150fps and more, making swinging through Manhattan as the web-slinger more exhilarating than ever. Heck, you can even achieve over 60fps at 8K if you have the television to display it. Also, be sure to check out the recently released Miles Morales for more Spider-Man-related fun.

ACER PREDATOR XB323QK 4K GAMING MONITOR

We reviewed this monitor in the September 2022 issue of *Maximum PC* and found it to be one of the best overall 4K gaming displays money can buy. It hits all the sweet spots for this kind of monitor—it's the perfect size at 32-inches, it has an excellent 144Hz refresh rate, and it supports Nvidia G-SYNC.

The IPS panel also has fantastic contrast and color reproduction, and there are specific modes for genres such as racing and sports. Just be careful—once you go 4K and get used to the kind of detail and frame rates offered by the RTX 4090 on a gaming monitor like this, it's very difficult to go back.

• $1200 • www.acer.com

© ACER, MARVEL, FOCUS ENTERTAINMENT

GEAR of the YEAR

AH YES, it's that time of the year when we can take a glance back over our shoulders and pick out our favorite pieces of tech from the last 12 months. Well, our favorite pieces of tech that we managed to get our hands on, at least. This year has been nothing short of thrilling—packed with great new tech and a return to glory for the tech industry after a couple of pandemic-affected years.

Thankfully, it's now far easier to acquire a GPU than this time last year. You were probably more likely to strike oil than get your hands on an Nvidia 30 series card at the end of 2021.

However, times have changed and we are now at the start of another new generation of hardware. We welcome with open arms Intel's 13th-gen Raptor Lake, AMD's Ryzen 7000 Series Zen 4 processors, and Nvidia 40 series GPUs, with AMD's GPU offerings looming. This also brings in new motherboards, a stronger case for upgrading to DDR5 RAM, and a whole lot more excitement on the horizon. Before we get ahead of ourselves and jump into the alluring pit of next-gen power, let's take a look at what products we rated the highest over the past year.

–THE MAXIMUM PC TEAM

SPECIAL MENTION

XGIMI HALO+ PROJECTOR

This doesn't fit the expectations of a conventional projector, and that's exactly what drew us to it. The mini projector is certainly becoming more prevalent in the market, but this quirky device from Xgimi is a great example of how good things can come in small packages. Around the size of the Apple Homepod, it packs a 1080p resolution, Android TV, HDMI connectivity, and a projection size of up to 200-inches. It's an all-in-one portable device with a decent built-in speaker from Harman Kardon. If you want to ditch your TV, this is a fun way to do it.

- **$849, us.xgimi.com**
- ***Reviewed: Maximum PC, May 2022***

CPU

INTEL CORE I9-13900K

After the impressive Core i9-12900K, we were more than excited about the release of Intel's Core i9-13900K. We get eight more cores and eight more threads than the latter, a higher turbo frequency, and a 6MB larger L3 cache size. Sure, these are expected to increase with a new generation, but seeing as the last iteration was a powerhouse, we're excited to see what machines we can run using this as the brain.

- **$599, www.intel.com**
- ***Reviewed: Maximum PC, Hol 2022***

★★★★★

GPU

GEFORCE RTX 4090 FOUNDERS EDITION

What better way to kick off the new year than with the latest and greatest GPUs to add to your build? Just like the Intel i9-13900K, we loved using the previous generation RTX 3090 and this is its newer and stronger successor. With the expected, but still exciting, blistering performance and the introduction of DLSS 3, this should remain one of the leading GPUs for this next generation and be great for futureproofing. Of course, there is a catch—it's pretty pricey!

- **$1,599, www.nvidia.com**
- ***Reviewed: Maximum PC, Dec 2022***

★★★★★

SSD

XPG GAMMIX S70 2TB

Picking a storage solution isn't as simple as just choosing the highest storage capacity at a decent price. Performance is key on these solid-state drives and XPG's GAMMIX S70 has to be one of the most balanced drives we've used over the past year. This speedy component won our 'So Solid Crew' SSD group test earlier this year thanks to impressive read/write speeds, good looks and keen pricing.

- **$259, www.xpg.com**
- ***Reviewed: Maximum PC, May 2022***

SSD

SK HYNIX PLATINUM P41 2TB

It was a close call between this and the XPG GAMMIX S70, and they both come in at the same price. Unfortunately for the SK Hynix Platinum P41, its read/write speeds just fell slightly short of its competitor in our testing. However, this SSD is no slouch at all—and if you can't get your hands on its rival and don't need a heatsink, this is a great storage solution for your new build.

- **$259, www.ssd.skhynix.com**
- ***Reviewed: Maximum PC, Oct 2022***

NZXT H7 FLOW

After testing all three new mid-tower H7 series cases from NZXT, the H7 Flow stood out the most to us. It's no surprise that NZXT has delivered yet another good-looking range of cases, but as well as looking pretty on your desk, it delivers great functionality, compatibility, and build quality all at a good price. The Elite is the most visually striking of the three models, and if you want a more minimalistic design, the standard variant might be the one for you. However, the standard H7 is priced the same as the Flow, which makes the Flow the obvious choice in our eyes.

- **$130, www.nzxt.com**
- ***Reviewed: Maximum PC, Nov 2022***

NZXT H1 2022

This a well-needed revision for a case that initially had a lot of potential. The original H1 case also had its fair share of problems, including a risk of setting on fire, which we can all agree isn't ideal. Thankfully, the 2022 model resolves that particular issue and also has a slightly bigger chassis, making it more compatible with larger GPUs. But this isn't just an ITX case, it's a kit—and an awesome one at that. For those who want a PC that looks like a console with greater future-proofing, the H1 2022 is a good shout.

- **$400, www.nzxt.com**
- ***Reviewed: Maximum PC, May 2022***

MONITOR

ALIENWARE 34 AW3423DW

We were, and still are, deeply impressed by this screen from Alienware. The 34in size seems to be the perfect balance for both work and play. Of course, being an Alienware product, it's aimed toward the gamer but it also works brilliantly for a range of different uses. It brings in some great features such as a QD OLED panel, 175Hz refresh rate, a 3,440x1,440 resolution, and super-fast pixel response. It's crystal clear with an equally spectacular performance and is one of the best monitors we've ever reviewed.

- **$1,299, www.dell.com**
- ***Reviewed: Maximum PC, Jun 2022***

★★★★★

MONITOR

BENQ MOBIUZ EX2710R

Like the Alienware offering (above), this BenQ Mobiuz is also aimed at gamers. However, because it's so good, you can easily use it for much more than just that. It features a 27-inch VA panel that delivers deeper blacks and stronger contrast compared with an IPS panel. It also has a refresh rate of 165Hz and a resolution of 1440p, which is at the sweet spot for most games. It's a great well-rounded display with an adaptive HDR mode that BenQ calls HDRi, which for the record, performs superbly.

- **$550, www.benq.com**
- ***Reviewed: Maximum PC, Jul 2022***

★★★★½

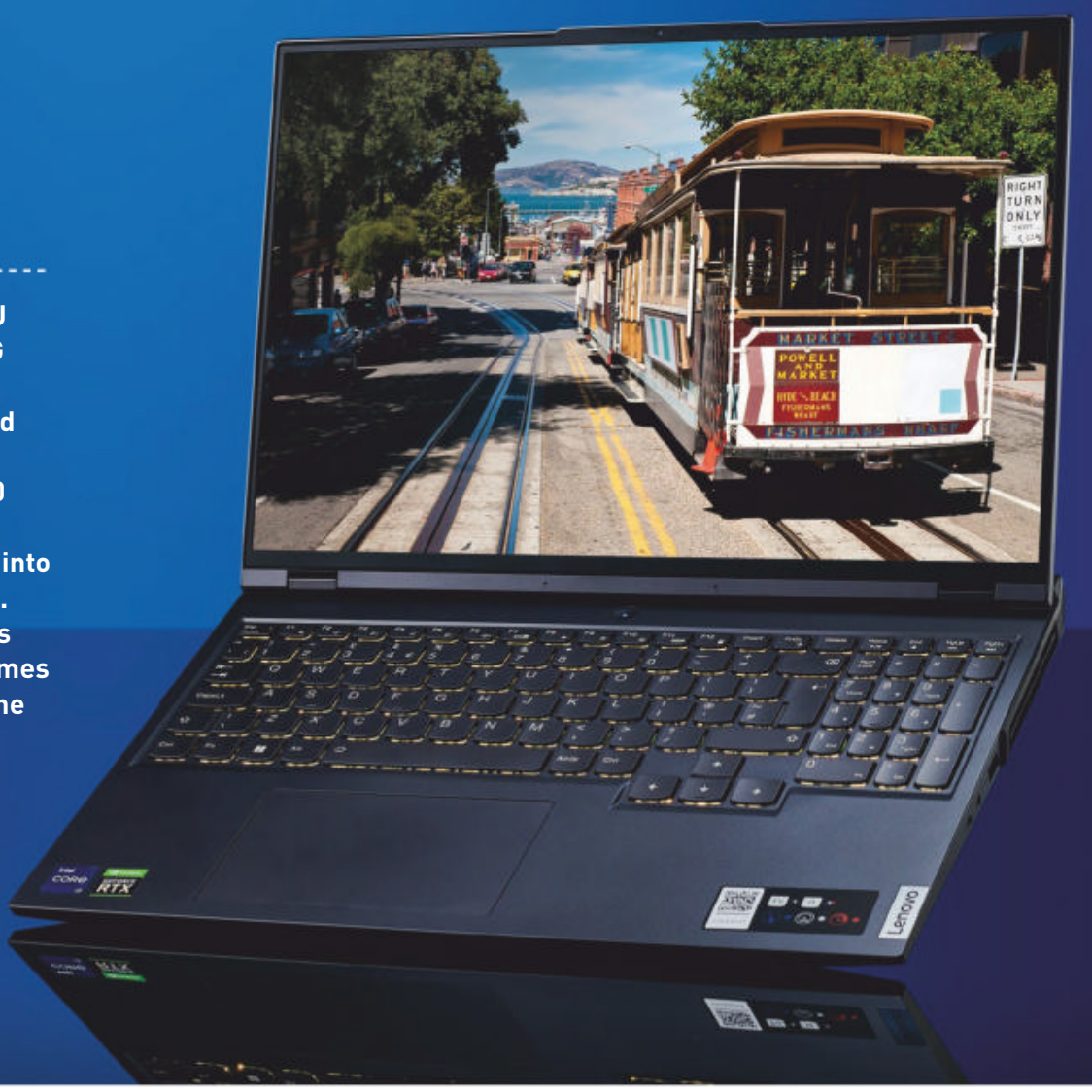
ASUS ROG FLOW X16

As much as we pride ourselves on the desktops we build, here at *Maximum PC*, we're also suckers for a good laptop. We have reviewed a few highly-rated laptops this past year, but they don't come much better than this. The Asus ROG Flow X16 ticks a lot of boxes, including having a stunning display—always a must for a laptop—and the mini-LED 1440P touch IPS panel doesn't disappoint either. Pair this with some blistering performance from the mobile AMD Ryzen 9 6900HS CP, an RTX 3070 Ti GPU, and DDR5, and you get a superb package overall. Oh yeah, and did we mention it's a two-in-one laptop as well?

- **$2,700, www.asus.com**
- ***Reviewed: Maximum PC, Sep 2022***

LAPTOP

LENOVO LEGION 5I PRO 2022



Similarly specced in terms of CPU, GPU and RAM performance to the Asus ROG Flow X16, the Lenovo Legion 5i Pro 2022 doesn't quite have all the bells and whistles or the same fit and finish of the two-in-one, but it's more than $800 cheaper. It still features a great crisp display, albeit you can't transform this into a tablet, but it's a great, vibrant screen. It's also fantastic at gaming—and that's what this machine is for, right? Sometimes it's just best to stick to the basics and the Legion 5i Pro does just that.

- **$1,899, www.lenovo.com**
- ***Reviewed: Maximum PC, Jun 2022***

SYSTEM

CORSAIR ONE I300

Another revised item that has been made even better with a few upgrades, the Corsair One i300 is a pricey but brilliant compact PC. If you want a pre-built system that resembles a console with a powerful Intel Core i9-12900K, RTX 3080 Ti GPU, and a whopping 64GB of DDR5 RAM, then the Corsair One i300 should be right up your street. It's extremely well-built and has plenty of future-proofing. Admittedly, the next-gen gear has come out since, but this is still a blisteringly fast machine that looks equally at home on a desk or under a TV.

- **$4,999, www.corsair.com**
- ***Reviewed: Maximum PC, April 2022***

MOUSE

CORSAIR M65 RGB ULTRA WIRED

The M65 has gained a well-deserved reputation as a cracking gaming mouse, and this RGB Ultra follows the principle of 'if it ain't broke, don't fix it'. It still maintains its wide stance, solid aluminum build, and distinctive 'sniper' button, yet the internals have been cranked up. It has plenty of programmable buttons and a smooth glide action. It's also comfortable, and has a snappy sensor. For $70, it offers great bang for your buck and we love it.

- **$70, www.corsair.com**
- ***Reviewed: Maximum PC, Hol 2021***

KEYBOARD

MOUNTAIN EVEREST MAX

As we mentioned in our review, this really is the Batman utility belt of keyboards—just look at it! It's jam-packed full of additional extras, including a media dock, wristrest, and a numpad that features four customizable macro switches. All of these add-ons are also detachable. Our unit came with some sweet Cherry MX Blue keys and pre-lubed Cherry stabilizers, with easy customization options as each key is hot-swappable. So, if you need to swap your key switches out down the line, that's no issue at all. It's a fantastic desk workstation but has a price tag to match.

- **$259, mountain.gg**
- ***Reviewed: Maximum PC, Nov 2022***

HEADPHONES

HYPERX CLOUD 2 WIRELESS

If you're looking to buy a gaming headset then there are a few major criteria it needs to meet. It needs to sound great, provide a high level of comfort for long periods of use, and be reasonably priced. Enter the HyperX Cloud 2 Wireless. As the name suggests, these cans offer cloud-like cushioning and can withstand long uses. Sound quality is also sublime, offering an immersive experience when gaming. Paired with a detachable microphone that has a clear pickup, you have yourself a gaming headset that can do it all.

- **$149, www.hyperxgaming.com**
- ***Reviewed: Maximum PC, Hol 2021***

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INTEL'S ARC ALCHEMIST ARCHITECTURE

Turning silicon into gold

Twenty-four years after exiting the dedicated graphics card market, Intel has returned. The landscape in those intervening years has changed so radically that what was once abandoned as an unnecessary side project now represents a major missing piece of Intel's technology portfolio. Put simply, Intel needs a competitive GPU offering, and Arc Alchemist is where it starts.

This isn't the first time Intel has tried to re-enter the GPU space. Larrabee was supposed to be a GPGPU (General Purpose computing on Graphics Processing Units), a chip that could do graphics but also other computational workloads, including scientific computing. Announced in 2008, a year later Intel said Larrabee would not be a consumer product but would instead go after the HPC (High-Performance Computing) market. Then Intel canceled Larrabee the following year, though some elements of the design lived on in the Xeon Phi offerings.

Now we've come full circle, as the third generation Xeon Phi, codenamed Knights Hill, was canceled in favor of a new high-performance architecture built from the ground up for the Aurora supercomputer. That's the Xe-HPC architecture, and there's also Xe-HPG (High-Performance Graphics) as a consumer variant that has now officially launched as Arc Alchemist. Let's pull back the heat spreader and find out what makes Alchemist tick. –JARRED WALTON

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A GROUND-UP ARCHITECTURAL REDESIGN

Intel isn't exactly new to the graphics arena—even in the past 24 years, it has released 12 generations (give or take, depending on how you want to count them) of GPU architectures. The old Intel i740 back in 1998? That was generation one—though Intel likes to claim that the 'real' generation one was in the first Core processors with integrated graphics in 2010. Either way, much has changed in the ensuing years. Where i740 had just a single pixel pipeline clocked at 220 MHz, the 12th generation Xe Graphics (used in Tiger Lake, Rocket Lake, Alder Lake, and now Raptor Lake) pack up to 768 universal shader pipelines and clock at up to 1450MHz.

Alchemist has some high-level similarities to the Gen 12 Graphics architecture, but it also changes a ton of stuff and delivers up to an order of magnitude increase in performance over the fastest Gen 12 solutions—and that's just in normal graphics workloads. Alchemist also packs in a whole bunch of new features and hardware that aren't available in any of the previous architectures.

Let's put things in perspective, here. Tiger Lake has 96 Execution Units for its Xe-LP GPU, and the various other parts of the graphics engine— including display controllers, media encoding blocks, and others—consume around 40 percent of the entire die area. With a die size of just 146mm^2, that means the Tiger Lake GPU only needs about 58mm^2.

In contrast, the smaller ACM-G11 Alchemist GPU measures 157mm^2, nearly three times the size of the integrated GPU, while the larger ACM-G10 chip checks in at a hefty 406mm^2.

Intel's Arc Alchemist comes in two forms, the larger and significantly more powerful ACM-G10, and the smaller ACM-G11 that trims down core counts.

The performance delivered by the Alchemist GPUs is the best indicator of everything that's changed, but let's cover the specifics. The new architecture includes full DirectX 12 Ultimate support: ray tracing hardware, Variable Rate Shading (VRS), mesh shaders, and sampler feedback. And by all measures, Intel didn't just tack on some hardware to check a box; the ray tracing units (RTUs) are capable and appear to be roughly on par with Nvidia's Ampere RT cores.

Beyond the full DX12 Ultimate support, Intel also added an XMX (Xe Matrix extension) Engine to the hardware. It's Intel's take on a high-density, lower-precision compute unit like Nvidia's tensor cores. The XMX engines are useful for AI and deep-learning workloads, an easy carryover from the Xe-HPC supercomputer realm. And like Nvidia's tensor cores and DLSS, XMX also powers XeSS (Xe Super Sampling), an AI-enhanced resolution upscaling solution.

Finally, Intel upgraded the media capabilities with a new Xe Media Engine that supports hardware encoding and decoding of AV1 and VP9 video, along with the usual H.264 and HEVC codecs. Both the larger and smaller Alchemist chips include dual media engines as well, further extending the video capabilities. Nvidia has matched Intel's Xe Media Engine with its latest Ada Lovelace

FASHIONABLY LATE TO THE PARTY

When Intel first started putting together its discrete graphics team back in late 2017, by hiring former AMD graphics guru Raja Koduri to head up the endeavor, there was initial talk of getting the first product out in 2020. That eventually morphed into a 2021 launch for DG1, or 'Dedicated Graphics 1', the first modern dedicated GPU from Intel.

To say DG1 sucked would be putting it nicely, as it was effectively the same Gen 12 graphics used in Tiger Lake. It used LPDDR4x memory, and it worked as a proof of concept, but the performance was no better—and sometimes worse—than the existing integrated solution. It was also clearly slower than the old GTX 1050. Who wants a dedicated graphics card that can't even consistently beat old and anemic hardware?

The Arc GPUs, aka DG2, were supposed to launch by the end of 2021, which was later pushed back to Q1 2022. Supply chain problems were reportedly to blame, as everything was still a mess throughout last year. Q1 could still have happened, and it nearly did, but the drivers weren't ready at the time.

One site reports that the main team responsible for the Arc drivers was based in Russia and that the Russian invasion of Ukraine in February this year created unexpected issues that took months to overcome.

Whatever the case, Intel instead opted for a messy staggered launch of Arc GPUs, starting in China back in March with the A380 and some of the mobile Arc GPUs. The company then moved on to a US launch of the A380 in August and finally the A770 and A750 launch in October.

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SPECIFICATIONS FOR INTEL'S ARC A-SERIES GRAPHICS CARDS

	A770 16GB	A750	A580	A380
Xe-Cores	32	28	24	8
GPU Shaders	4,096	3,584	3,072	1,024
XMX Engines	512	448	384	128
Ray Tracing Units	32	28	24	8
Boost Clock (MHz)	2,100	2,050	1,700	2,000
VRAM Speed (Gbps)	17.5	16	16	15.5
VRAM (GB)	16/8	8	8	6
VRAM Bus Width	256	256	256	96
L2 Cache	16	16	16	6
ROPs	128	128	128	32
TMUs	256	224	192	64
TFLOPS FP32	17.2	14.7	10.4	4.1
TFLOPS FP16 (INT8)	138 (275)	118 (235)	84 (167)	33 (66)
Bandwidth (GB/s)	560	512	512	186
TBP (Watts)	225	225	175	75

Specifications for Intel's Arc A-series graphics cards, built on TSMC's N6 process node—the A770 8GB has the same specs as the 16GB, except with 16 Gbps VRAM.

SPEEDS AND FEEDS

Intel has two different GPUs for Alchemist, and our table shows the specifications for the four desktop graphics cards that use these chips. Besides the desktop models, Intel also has five mobile variants plus three 'Pro' models—though they aren't really aimed at professionals, given all three use the smaller ACM-G11 die that offers rather mediocre performance.

Intel's first iteration of Arc GPUs ends up a bit unbalanced in some areas, for example, the 128 ROPs (Render Outputs) and 256-bit memory interfaces that are present on the three higher-tier GPUs. Power efficiency is also a little way behind AMD and Nvidia, considering that performance on the 225W A770 and A750 in general keep pace with AMD and Nvidia cards that only consume around 160W–180W.

We're still waiting to see whether Intel actually launches the Arc A580 to retailers, and if so, how much it will cost. Given the A750 already sits at the $289 price point, we expect the A580 will cost $249 or less, and with lower clocks than its siblings, it should hopefully land closer to $200 than $250.

It's also worth noting that Intel's stated boost clocks are pretty conservative. In testing, we routinely saw the A770 running at 2.4 GHz and the A750 at 2.35–2.4 GHz. Similarly, the A380 we evaluated—though, granted, that was a factory overclocked Gunnir model—consistently ran at 2.45 GHz. That's good, though, as we'd much rather see companies under-promise and over-deliver on clock speeds.

LOOKING TO THE FUTURE & LEARNING OUR ABCs

Arc might be the first dedicated GPU from Intel since the late 1990s, but it's already looking toward future offerings. According to Intel Fellow, Tom Petersen, most of the Arc team has now moved on to the next generation Battlemage, which is well underway. However, having learned a lesson or two from the Alchemist launch, Intel isn't giving any firm dates for Battlemage yet.

What we do know is that Intel will be looking at ways to improve performance and will likely move to a newer process node. Alchemist uses TSMC's N6, which is a refined version of the N7 process that was launched back in 2019. AMD and Nvidia are moving on to 5nm-class nodes for their latest GPU architectures, and next year, it would be unthinkable for Intel to launch a new GPU that doesn't at least use a 5nm process.

Beyond Battlemage, Intel has plans for Celestial and Druid. Intel will be taking an ABCs approach to its GPU names going forward, with products still under the Arc brand but with a different letter at the front. That means we'll have Arc B-series GPUs when Battlemage arrives, followed by C-series with Celestial, and so on. What comes after Druid, though... Elves and Fairies, perhaps?

Given the delayed launch and arrival of the Arc Alchemist GPUs, it's possible that we'll see Battlemage arrive sometime in 2023. Intel has been executing a consistent yearly release cadence on its CPUs for quite a while, albeit with occasional stumbles along the way.

Given that many businesses function on a rotating yearly cycle of upgrades, it wouldn't be such a terrible thing if Intel could start offering new graphics products alongside its future CPUs.

Or perhaps that's just wishful thinking on our part.

architecture that features dual NVENC units, but for the time being, it's only available on the RTX 4090.

EVERYTHING IS XE-CELLENT

Intel may have gone somewhat overboard with the use of 'Xe' in naming the various parts of its Alchemist GPUs. Xe-Cores, with Xe Vector Engines (XVE), Xe Matrix eXtensions (XMX), Xe Media Engines, Xe Display Engines, and an Xe Graphics Pipeline. OK, we get it, this is the Xe family of GPUs and everything inside them is now Xe-branded. Beyond the names, there are many fundamental similarities between Intel's latest architecture and competing architectures from AMD and Nvidia.

Each XVE can perform up to 16 FP32 operations, 32 half-precision FP16 ops—or 64 INT8 operations—per clock cycle. To be clear, that's really eight general-purpose 32-bit floating-point operations per clock, or 128 operations per Xe-Core per clock, except FMA operations (Fused Multiple Add) count as two operations. Graphics and AI workloads use FMA extensively, so companies often just refer to the peak theoretical ops/clock.

Nvidia's previous Ampere architecture as well as the new Ada Lovelace also have 128 shader pipelines per Streaming Multiprocessor (SM), with FMA ops counting double, so Xe-Cores effectively

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Intel says XeSS is coming to over 20 games, and is now available in at least half of the titles above.

EARLY XESS IMPRESSIONS

Considering Arc GPUs have only been shipping for a little over a month now—not counting the 'for China only' mobile and A380 launches that happened this past spring—things aren't looking too bad for XeSS adoption. The XeSS SDK is publicly available, and we were able to give it a shot in a handful of games.

It's important to note that XeSS can run in two modes: XMX mode for Arc GPUs, and DP4a (a form of INT8) for all other GPUs. The quality of the two modes is not identical. That's because DP4a generally means far less computational power, which in turn, means it needs to strike a different balance between quality and compute. The DP4a support is interesting as it means XeSS, like AMD's FSR and FSR2, can run on any modern GPU with at least Shader Level 6.4 hardware.

Looking just at the Arc GPUs, XeSS looks remarkably close to native resolution in Quality mode (2x upscaling) and improved performance by 20 to 25 percent, while the loss of image fidelity in Balanced and Performance modes becomes more noticeable alongside larger performance gains. We also saw some rendering errors with XeSS in *Death Stranding*, where floating 'icons' from other users exhibited ghosting. That's probably an implementation problem with the game, rather than a fundamental flaw with XeSS.

Perhaps more perplexing is that XeSS did little to improve performance on the Arc A380. It seems like the algorithm needs the computational resources of at least an A750, or maybe an A580, to really provide a boost to performance. In the games we tested, the A380 performance only increased by 5–15 percent, and that was even with Performance mode (4x upscaling).

For now, we can't help but feel that AMD's FSR 2.1 offers a better overall solution for developers who want a good upscaling algorithm that works on any GPU. XeSS might technically deliver better image quality on Arc GPUs, but those are currently such a small part of the market that it doesn't make much sense to worry unduly about them—unless, of course, Intel is footing the bill for developer costs.

map to Nvidia SMs when doing a high-level comparison of GPUs. It sounds as though AMD's next-generation RDNA 3 Compute Units will also be moving to 128 shader pipelines per Compute Unit, but we'll have more information about that in the coming months.

The XMX engines offer up to four times the throughput at equivalent precision as the vector units, so a single XMX unit can do up to 128 FP16 (or BF16) ops/clock. Intel uses a four-deep systolic array in its XMX units, and besides 16-bit numerical formats, it also supports INT8 at double the throughput (256 ops/clock), or INT4/INT2 at double again the rate (512 ops/clock). AI inferencing workloads often use INT8, so it does have practical applications, and as far as we're aware, Intel is using INT8 with XeSS.

Intel's Xe-Cores can co-issue FP, INT (and extended math), and XMX instructions at the same time. That makes the capabilities quite similar again to what Nvidia has been doing, except Nvidia's Ampere and Ada architectures have half of the CUDA cores doing pure FP32 while the other half can do FP32 or INT32 (and extended match).

INTEGRATED ELECTRONIC

Besides the XVE and XMX blocks, each Xe-Core includes 192KB of shared L1

cache, a Thread Sorting Unit, a Ray Tracing Unit, texture samplers, render outputs, and some other hardware. Intel then groups four Xe-Cores plus the other miscellaneous bits and pieces into what it calls a Render Slice, which is the next step up from the Xe-Core.

We haven't talked about the RTUs yet, and Intel has provided a fair amount of detail on its ray-tracing capabilities. Each RTU contains two ray traversal pipelines and can compute up to 12 ray/box intersections for Bounding Volume Hierarchy (BVH) traversal, or one ray/triangle intersection per cycle. Intel also has a dedicated BVH cache that should help reduce the memory bandwidth demands of ray tracing.

Nvidia is a bit cagey about the exact throughput of its BVH traversal hardware, but we do know that Ampere can do up to two ray/triangle intersections per clock, and Ada effectively doubles that rate. AMD in contrast can only do four ray/box intersections per clock or one ray/triangle intersection. By those metrics, Intel's ray tracing hardware mostly matches Nvidia Ampere, and both come in quite a bit ahead of AMD's RDNA 2—though, of course, RDNA 3 can and likely will upgrade AMD's Ray Accelerators.

The basic building block for Intel's Arc GPUs is the Xe-Core, which features 16 Xe Vector Engines (formerly called Execution Units) and 16 XMX Engines.

The Thread Sorting Units (TSUs) are also important, as they help to ensure the various Vector Engines receive similar workloads to help optimize throughput. This sounds like what Nvidia is doing with its new Shader Execution Reordering (SER) in its Ada Lovelace architecture, except, unlike SER, Intel says the TSUs don't require any special developer integration. They're there and they do their best to sort the various threads to the appropriate execution units.

These Render Slices then get duplicated, linked to a memory fabric and L2 cache, and are packaged together with the media, display, memory controllers, PCI Express interface, and a few other pieces to create the full graphics chip. Intel can disable individual Xe-Cores to improve yields, so for example, the maximum configuration of the large ACM-G10 die has 32 Xe-Cores, which is what goes into the Arc A770 GPU. The Arc

INTEL'S AMBITIOUS MEDIA FUNCTIONALITY

Graphics cards have included support for video decoding and encoding for a while, with a few notable exceptions such as AMD's Navi 24-based cards. The most popular video codec is still H.264, first released back in 2003 before Blu-ray even became a thing. H.264 has been updated a few times over the years, but the core features have been around since 2005.

One of the reasons for the proliferation of H.264 is that MPEG LA, the group in charge of administering patent licenses, declared in 2010 that internet video that was available for free viewing didn't need to pay licensing fees. Coupled with the explosion of YouTube, nearly every new device for over a decade has had H.264 support.

But H.264 has long since been surpassed by newer codecs. H.265 (aka, HEVC) promises equal quality with 25 to 50 percent better compression rates, or substantially improved video quality at the same bitrate. The problem is that licensing requirements for HEVC are more strictly enforced and the quality gains often aren't that substantial.

Intel Arc graphics cards include two Xe Media Engines, each with support for up to 8K encoding and decoding in the most popular video codecs.

AV1 was developed as a royalty-free alternative to HEVC and other video standards. Intel's Arc GPUs are the first to have hardware support for AV1, with the ability to encode and decode up to 8K60 12-bit HDR content. The GPUs also support VP9 (developed by Google and used on YouTube).

In testing, we found that the Arc GPUs consistently offered some of the best quality encodes at various bitrates for both 1080p and 4K video, often defeating CPU-based algorithms that take significantly longer to encode.

However, AV1 didn't prove to be any higher quality than HEVC, so its main selling point is that it should be free. But that feature alone could be enough to ensure that it will eventually supplant H.264 as the codec of choice for future video streaming services.

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A750 uses the same chip but with only 28 Xe-Cores enabled, and the A580 drops down to 24 Xe-Cores.

PRACTICING ALCHEMY

We haven't had a serious third competitor in the PC graphics space since 3dfx and S3 exited the market about 20 years ago. It's been a two-horse race since then, with AMD and Nvidia trading blows, though Nvidia has taken the lead over the last few generations of hardware. Intel almost re-entered the GPU market more than a decade ago with Larrabee before pulling the plug on that project, a decision that has perhaps haunted it over the following years. Now, it's looking to right that wrong with Arc Alchemist.

There's lots of good stuff in Alchemist, and if it had arrived last year, as originally planned, it could have really made a splash. You can see how the Arc A770, A750, and A380 stack up against the AMD and Nvidia competition in our reviews, and for a first true effort at a dedicated graphics card (we don't really count last year's DG1), Alchemist shows plenty of promise. Of course, if Arc had arrived in the middle of the pandemic and crypto mining boom of late 2021, it would have cost much more than we're now seeing.

With this first step out of the way, Intel now needs to see through its plans to continue improving the core GPU architecture. It's already laid out a roadmap of future parts, but the competition isn't standing still, and getting hardware into gamers' systems and developers' hands will be critical for future success. Intel also needs to continue hammering away on its drivers to shore up any deficiencies, which is something we've noted in our reviews of the various Arc cards.

However, the one thing we know for certain is that creating a successful family of graphics cards isn't a straightforward process. Intel is one of the few companies around with the size and resources—and patents—to enter the market at this stage of the game. Now the company just needs to iterate on the Alchemist foundation, and perhaps its future products can be transformed into gold.

ARC AND RESIZABLE BAR

AMD was the first to support PCIe's Resizable BAR (Base Address Register) feature, which had existed for some time as an option to potentially improve the performance of integrated graphics solutions.

With its Radeon RX 6000-series graphics cards, AMD discovered that it could boost performance by around 10 percent using ReBAR to provide the CPU with direct access to all the GPU memory—instead of the usual 256MB at a time. It called the feature Smart Access Memory (SAM) and enabled support on its 500-series motherboard chipsets.

Intel and Nvidia eventually followed suit, with the RTX 30-series and Intel chipsets going as far back as the 300-series (mostly Z390 and later) getting support. ReBAR requires both motherboard BIOS support as well as a compatible graphics card to provide any benefit—and that's where things get a bit interesting.

With its Arc GPUs, Intel designed the hardware and drivers from the start to make use of ReBAR. While AMD GPUs might gain an additional 10 percent in performance, and Nvidia's GPUs often get around a 5 percent improvement, ReBAR boosts Arc GPU performance by as much as 30 percent.

It's such a significant increase that Intel lists ReBAR as a requirement for Arc GPUs, which means you need at least a 10th-generation Intel CPU or an AMD Ryzen 5000-series CPU to use ReBAR—although there are some earlier CPUs and motherboards that also support the feature now. When asked about running Arc GPUs on older platforms that don't support ReBAR, Intel's Tom Petersen replied, "If you don't have a PC with ReBAR support, you should just go out and buy an RTX 3060 rather than an Arc GPU."

Independent testing confirms the 20–30 percent performance loss when running Arc GPUs on systems that lack ReBAR.

Intel Arc graphics cards list resizable BAR support as a base requirement, so you will need a relatively modern motherboard.

CENTERFOLD

PERFORMANCE GEAR LAID BARE

Samsung Odyssey Ark Gaming Monitor

THERE'S BIG, then there's big. The Samsung Odyssey Ark Gaming Monitor is so big that it wouldn't fit in my apartment without a serious upgrade to my desk. Or, more accurately, a whole new apartment.

In the landscape configuration, sitting at the normal distance of around two feet away from the screen, it fills your entire vision, making for an engrossing if slightly frightening gaming experience. In its portrait configuration, which you can achieve by smoothly rotating it by hand, you get the equivalent of three 30-inch monitors stacked on top of each other, letting you game while watching TV, or multitasking in general.

2 DESIGN

The Odyssey Ark weighs 41.5kg on its stand, takes three people to move it, and feels like a gym workout to get it out of the box and piece it together. Once it is assembled, though, it feels sturdy and well-built. We wish the transformation from landscape to portrait was automated, but it's easy and smooth to turn it by hand. It also has a thin bezel, although the 1000R curve looks deep when not viewed straight-on.

Working in landscape was a privacy nightmare, as anyone sitting within around 50 feet can easily see what you're doing. I also found it much less useful in the portrait ('Cockpit') mode, because the monitor wasn't able to display my game in HDR and my content in SDR, while I had to uncomfortably crane my neck in order to view whatever was at the top of the screen.

What a gaming experience this display offers though—just what you'd expect for a $3,500 price tag.

1 CONNECTIVITY

There's only one cable needed to connect to the display itself, as all of the power, networking, and video go through a separate box. We like this as it means no fumbling behind the back of the huge screen when you want to add a new games console, for example. PC fans will be confused by the lack of DisplayPort input, but there are four HDMI 2.1 inputs, enough for 4K at up to 120Hz.

3 CONTROL

The Odyssey Ark comes with two remote controls, one that looks like a regular streamer remote and another that looks like a calculator, complete with a solar panel at the top. The Ark Dial has a huge wheel for navigation and buttons that allow you to rearrange what's displayed in Cockpit mode. We found it needlessly big and confusing to use.

OLED monitors, such as the Asus ROG Swift PG42UQ, offer the best HDR experience.

THE TRUTH ABOUT HDR

Fake technological news or the ultimate visual experience? *Jeremy Laird* investigates the state of HDR technology on the PC today

BORDERLINE UBIQUITOUS, but a little bit baffling. That's HDR or high dynamic range image rendering. It's everywhere, but also quite confusing, especially on the PC. With numerous competing and overlapping standards, all manner of supporting screen technologies, and patchy software support, using HDR on a PC can be a frustrating experience.

Even knowing if HDR is working correctly can be tricky. That's a particular problem on the PC, given that many so-called HDR monitors can't actually display HDR visuals. Meanwhile, enabling HDR can do weird things to conventional SDR content and graphics. It's a patchy experience.

But here's the thing. When it's done right, HDR is spectacular. Good enough that once you've gone HDR, you won't want to go back. From eye-popping in-game sizzle to deep, dark moody cinematic thrills, HDR adds a level of realism and immersion that's quite unlike any other display technology.

That's why we've done the donkey work for you with this comprehensive HDR explainer. Over the next four pages, you'll learn exactly what HDR is, what standards to look out for, some tips for choosing a good HDR monitor, and how to get HDR set up correctly on your PC for watching HDR video and playing HDR games.

AT ITS SIMPLEST, HDR or high dynamic range refers to any display technology that increases the gap between the brightest and darkest image elements. In other words, an HDR display can display both brighter and darker images than a conventional SDR or standard dynamic range screen. The clever bit is that a true HDR display can go both brighter and darker at the same time, combining both ends of dynamic range in a single image.

The idea behind HDR is to more accurately mimic real-world lighting. A conventional LCD monitor, for instance, will typically offer a contrast ratio of 1,000:1. That means the brightness image element is 1,000 times brighter than the darkest. If that sounds like a lot, real-world contrast can involve light sources that are millions upon millions of times brighter than others. Ambient outdoor daylight is roughly one million times brighter than at night. That ratio gets orders of magnitude bigger if you move indoors and block out even more light.

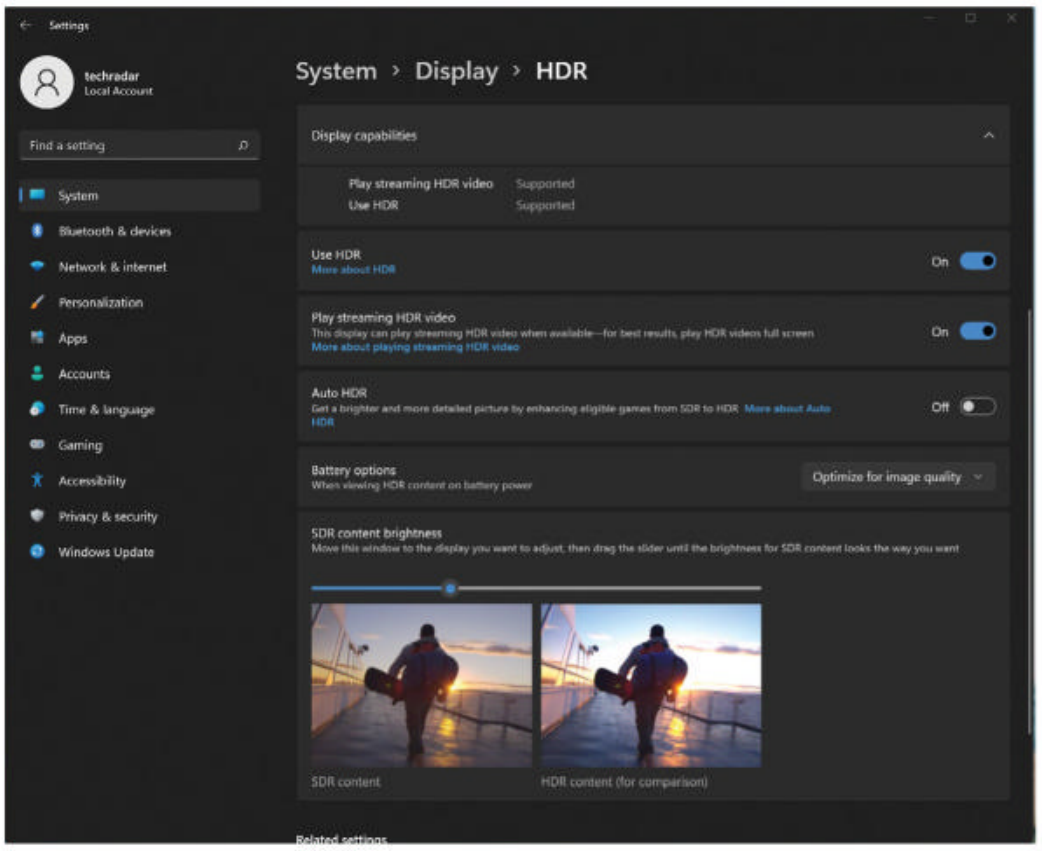
Regular monitors don't have this broad contrast because they lack performance at both ends of the scale. They leak too much light when attempting to render darker tones and have limited maximum brightness. The resulting image is both less vibrant at the high end and lacking in shadow detail at the low end. In short, the image is flat and unrealistic. HDR displays also tend to increase fidelity across the board. Specifically, they support larger color gamuts that enable much more image detail.

IMMEASURABLE IMPROVEMENTS

By exactly how much HDR displays improve over conventional SDR screens is where things begin to get tricky. That's because there's no single, overarching standard for HDR, both in terms of encoding content and ultimately displaying it. With HDTVs, there are two main standards for encoding HDR visuals, known as HDR10 and DolbyVision. Broadly, HDR10 is the generic, entry-level standard that pretty much all TV sets support, while DolbyVision is a proprietary standard from Dolby. There are a few lesser-used standards, such as HDR10+, that you may see flagged up on streaming services such as Amazon, which offer increased performance but bring compatibility issues.

On the PC, only HDR10 is supported, so there's no need to be distracted by the HDR format war. What's more, Windows supports HDR10 by default and pretty much all recent graphics cards are likewise HDR-capable. So, it's likely there's nothing you need to do to your PC itself to add HDR support. In hardware terms, then, it all comes down to your monitor. And that's where the real difficulties begin.

Vesa's DisplayHDR certification system has become the industry standard for rating the HDR capability of PC monitors. Sadly, it's not really fit for purpose. It consists of a range of certification levels, each progressively more demanding. But it's arguably only the highest certification level that guarantees genuine HDR capability.



Enabling HDR on the PC should be as simple as flicking a single switch...

Take the entry-level DisplayHDR 400 certification. It has almost no requirements. It doesn't demand local dimming. It doesn't dictate broader color coverage. It only requires a maximum brightness of at least 400 nits at a 1,000:1 contrast ratio, plus HDR10 signal processing.

With LCD monitors, to display something approaching a true HDR experience, you need full-array local dimming technology with hundreds of zones, brightness approaching 1,000 nits, and coverage of the DCI-P3 gamut of around 95 percent or higher. With that in mind, even many DisplayHDR 600 monitors don't come close to true HDR and even some DisplayHDR 1000 panels aren't the real deal.

Samsung's Neo G9 mini-LED tech gives the best LCD-based HDR performance currently available.

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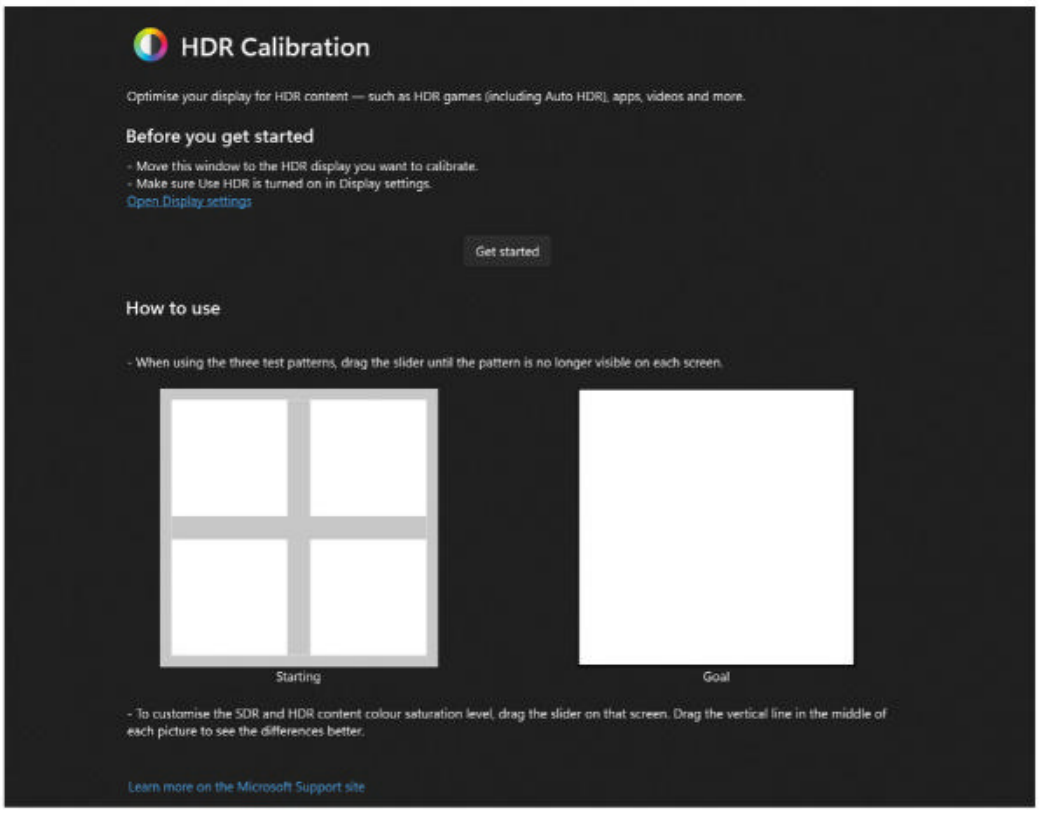


Microsoft provides a handy tool for calibrating HDR displays.

For starters, 600 nits—as the standard implies—arguably isn't bright enough. But the real problem is the rudimentary local dimming requirement for DisplayHDR 600. Many DisplayHDR 600 monitors have a small number of edge-lit dimming zones, typically 16. The consequence is that the backlight can only be controlled in large vertical stripes across the panel. When you consider that the point of HDR is to be able, for instance, to show a small, bright light source on a dark background, that's never going to fly.

In truth, it's only when you get to monitors with full-array local dimming and a thousand or more zones that you can have something approaching a proper HDR experience. With more zones comes improved lighting control and a reduction of problems like halos around bright objects, caused by the size of individual backlight zones being too large to constrain the increased backlighting within the borders of brighter image elements. By way of example, consider a backlight with, say, 144 dimming zones. Now, a 4K display has a little over eight million individual pixels. So, with a 256-zone backlight, each dimming zone lights nearly 60,000 pixels. That's not exactly precision lighting.

Thought of another way, that 144-zone array translated in a panel resolution is 16x9 pixels. 'Blocky' doesn't even begin to describe it. Even with 1,152 zones, you're looking at a backlight resolution of just 48x24 zones. In an ideal world, then, each pixel would be its own light source. As it happens, that's exactly what you get with an OLED panel.

VESA's DisplayHDR certification scheme arguably isn't fit for purpose.

Summary of Performance Differences by Tier

VESA CERTIFIED DisplayHDR	Minimum Peak Luminance *Brightness in cd/m²*	Range of Color *Color Gamut*	Typical Dimming Technology	Maximum Black Level Luminance *Brightness in cd/m²*	Maximum Backlight Adjustment Latency *Number of Video Frames*
DisplayHDR 400	400	sRGB	Screen-level	0.4	8
DisplayHDR 500	500	WCG*	Zone-level	0.1	8
DisplayHDR 600	600	WCG*	Zone-level	0.1	8
DisplayHDR 1000	1000	WCG*	Zone-level	0.05	8
DisplayHDR 1400	1400	WCG*	Zone-level	0.02	8
DisplayHDR True Black 400	400	WCG*	Pixel-level	0.0005	2
DisplayHDR True Black 500	500	WCG*	Pixel-level	0.0005	2
DisplayHDR True Black 600	600	WCG*	Pixel-level	0.0005	2

*Wide Color Gamut

LIMITED PEAK BRIGHTNESS

In an OLED panel, you can have two pixels side-by-side, one switched completely off and emitting no light, the other at maximum brightness. Each pixel is its own light source. That simply isn't possible with LCD tech. The snag with existing OLED technology is limited peak brightness, particularly over large areas of the screen. OLED panels are pretty good at small bright objects and can hit as much as 1,000 nits. But they can't do high brightness across the whole panel, typically maxing out below 200 nits. Nearly all HDR content is mastered with displays capable of at least 1,000 nits of full-screen brightness in mind. So, OLED screens simply can't do brighter HDR content full justice.

The consequence is that you need to be careful when choosing an HDR monitor. Don't assume that even a high level of HDR certification such as DisplayHDR 1000 guarantees a good HDR experience, as it doesn't. More generally, be aware that there's really no single display technology yet available that delivers the ideal HDR experience. All the existing options come with pros and cons.

With that in mind, let's assume you've got a half-decent HDR monitor. It's probably not absolutely the real HDR deal. But it's a significant step up on a conventional SDR screen. The next challenge is ensuring everything is set up properly. You'd hope it was just a simple case of flicking a single switch to enable HDR. Strictly speaking, it is. Or a few mouse clicks, at most. Right-click the desktop in Windows, select "Display settings", toggle the "Use HDR" and you're golden. Except, you're almost certainly not. Part of the problem is that various displays implement HDR differently. There's no universal standard. You may or may not need to enable HDR on the display itself first, for instance. Most displays also offer a range of HDR modes and no clear indication of which to choose or why.

Microsoft has attempted to expedite some aspects of HDR calibration via the Windows HDR Calibration app, which can be downloaded free from the Windows Store. It takes you through a series of test images designed to optimize the display stack for HDR output. The idea is to map the capabilities of your panel and create a color profile that maximizes image detail at both ends of the luminance scale, bright and dark. You can also tweak the overall saturation of HDR colors using the tool.

© MICROSOFT, VESA

In our experience, it gives mixed results. What it also doesn't address is the problem of rendering SDR content on a display running in HDR mode. In an ideal world, any given monitor would display both HDR and SDR content correctly at the same time—in other words, without the need to manually switch between modes depending on the kind of content you're viewing or playing. In practice, it's an absolute mess.

Windows does provide a slider for adjusting the brightness of SDR content in HDR mode. You can find it in Display settings by clicking the 'More about HDR' in the Use HDR selector bar. It's somewhat helpful, but what it doesn't do is directly address the problem of correctly tone-mapping SDR colors when running a monitor in HDR.

CARTOONISH COLORS

In our experience, most PC monitors default to the incorrect color mode when HDR is enabled, resulting in anything from flat, washed-out SDR output with poor contrast all the way to zany, cartoonish, and oversaturated SDR colors. The problem here involves Windows reading the color profile data from the display and mapping SDR colors to the native gamut supported by the display. SDR colors are, in effect, being stretched to match the higher fidelity gamut of the display.

The problem is that if the display is running in anything other than that native gamut or color space, SDR output goes haywire. With some monitors, it's a relatively simple task to jump into the OSD menu and select the correct HDR color profile. But it isn't always obvious where to find that or what the native profile is, which can be frustrating. What's more, some displays simply aren't well enough calibrated to ever show SDR colors accurately in HDR mode, regardless of the mode you choose.

That can be a particular pain for gaming, given that many titles require your PC's global HDR mode setting to be enabled to support HDR in-game. So, if you happen to have a monitor that doesn't render SDR colors well in HDR mode, you must toggle HDR on and off every time you boot up your favorite HDR-supporting game. It's a chore.

Our expectation is that these problems will remain to at least some extent until the display industry converges around a single-panel technology based on per-pixel lighting. Whether that's OLED or MicroLED is yet to be determined. However, eventually, nearly all monitors are likely to be based on one of those two technologies or something closely related to them. There should also be more consistency across displays in terms of HDR capability. At that point, HDR mode will become the default setting and correctly mapping SDR colors will be the norm.

Until then, HDR will remain a hit-and-miss technology. While the very best HDR displays today deliver a pretty spectacular experience, they are the exception—and an expensive exception at all. But the reality, for now, is that most vaguely affordable sub-$1,000 monitors really only scratch at the surface of what HDR can and should deliver. HDR, then, isn't entirely fake news. There are real benefits to be had right now.

HDR hotness! At its best, HDR display technology is like nothing else.

© ASUS

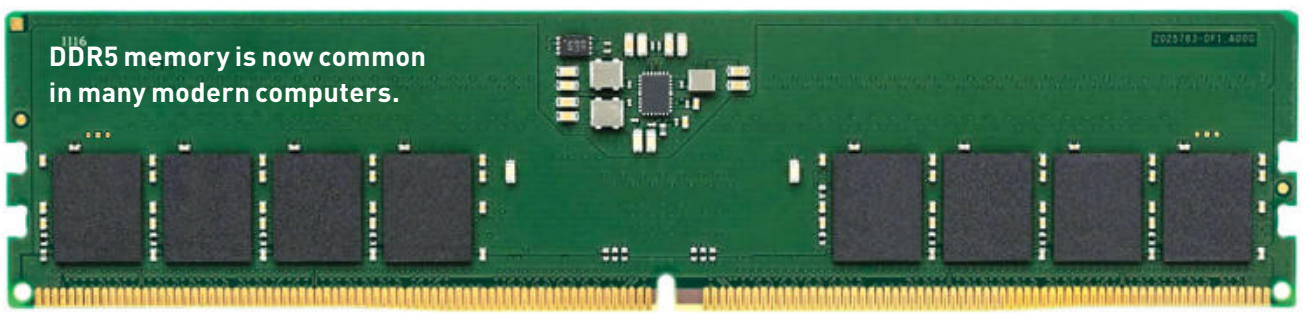
LIFTING THE LID ON DDR5

The latest RAM technology has hit the mainstream, but what difference does it make? *Darien Graham-Smith* decodes the data to find out

IF YOU BUY a new computer today, it may well be using DDR5 memory. As the name suggests, this represents the fifth generation of the DDR (double data rate) RAM standard, originally laid down in the year 2000. Of course, if you want to delve into the history of memory you can go much further back than that—the Joint Electron Device Engineering Council (JEDEC) has been developing standards for electronic storage since 1944.

For now, though, let's focus on how DDR5 builds on its predecessor. DDR4 is a versatile standard that officially comes in seven varieties, dubbed DDR4-1600, 1866, 2133, 2400, 2666, 2933, and 3200. You might assume that the numbers indicate the speed at which the different variants run, and that's basically right—although since DDR transfers data at twice the speed of the internal clock, a DDR-1600 module actually runs at 800MHz, and so forth.

Take a look at DDR5 options and you'll see that they start at DDR5-4800 and go all the way up to DDR5-7200. That's an enormous increase, with the top frequencies more than doubling—but that doesn't necessarily mean that DDR5 RAM will run twice as quickly.



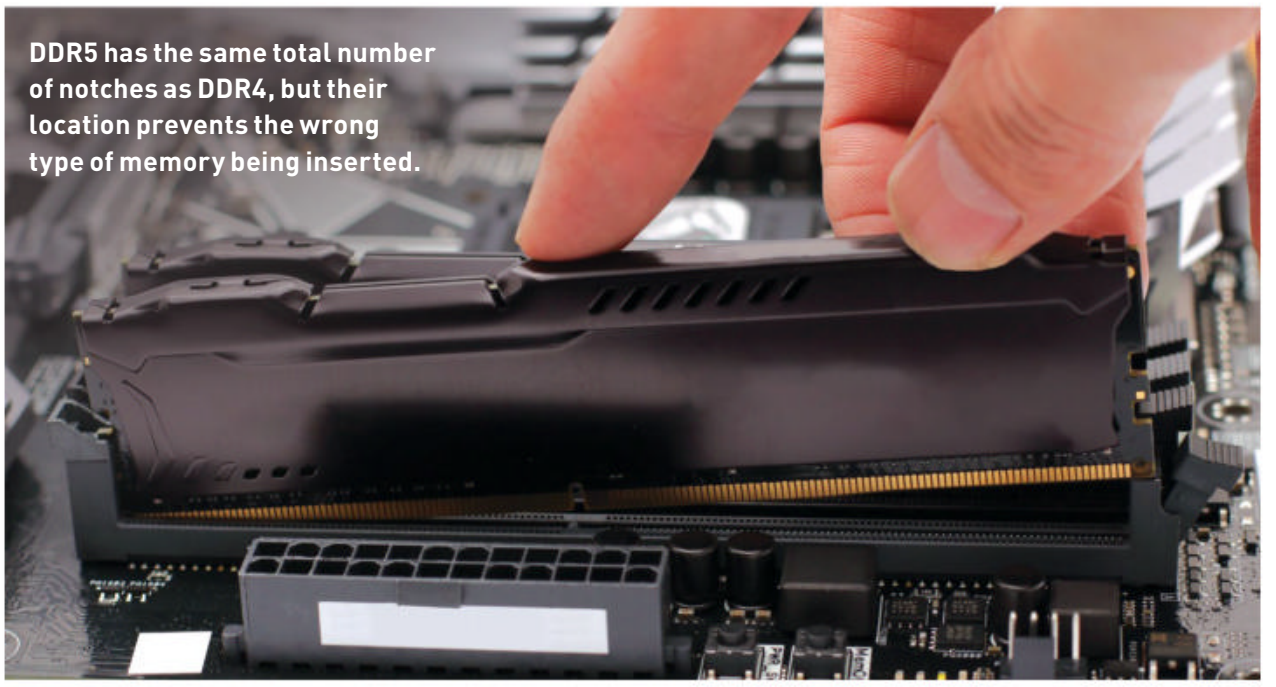
DDR5 memory is now common in many modern computers.

THE SECRET OF LATENCY

The chips in a RAM module are fast, but they aren't capable of reading or writing a full 64-bit chunk of data every clock cycle. If you look at the specifications of modern DIMMs, you'll see that each one has a specified set of timings that indicate how many clock cycles it actually takes to store and fetch data. These are normally written as a series of four numbers, say 16-20-20-34.

To make sense of these numbers, you need to know that RAM is arranged as a virtual grid: the latter three numbers tell you how many clock cycles it takes to select a specific 'row' of memory for reading, and the first one tells you how many cycles it will then take to retrieve data from the desired 'column'.

This initial value is called CAS latency, which stands for 'column address strobe' and, along with the clock frequency, it's normally the most significant factor in determining the relative speed of a RAM module. That's because most RAM operations involve reading a series of values from consecutive columns within a row, so the overhead of row selection comes up relatively infrequently, whereas CAS latency applies to every value that's accessed. Therefore, a DDR4-3200 module with the timings above would be able to provide one chunk of data every 16 clock cycles; since the clock runs at 1.6GHz (double data rate, remember), that means it takes 10ns for the RAM module to complete a request for data from a specified location in an active row.



DDR5 has the same total number of notches as DDR4, but their location prevents the wrong type of memory being inserted.

Installing matching DIMMs in paired slots means they can run in parallel.

You can easily check on the timings of your own RAM, either by checking the BIOS or by installing a free tool for Windows such as HWiNFO64 (hwinfo.com). This offers a table showing the timings and clock speed of each DIMM in your system, while a summary reveals the total installed memory, type, clock speed, and channel mode, which we'll discuss below.

Ideally, for the best performance, you want a high clock speed and low timing figures. Unfortunately, while it's comparatively simple to make memory modules run at ever-higher frequencies, it's much harder and more expensive to make the actual memory cells respond more quickly, so faster DIMMs tend to have higher latencies, at least in terms of clock cycles. As a result, the difference in performance between DDR4 and DDR5 modules is far smaller than you might expect (see box, page 59).

DENSITY AND POWER

Clock speeds aren't the only changes between generations of DDR. As manufacturing processes have improved, DDR data densities have increased, enabling computers to support ever-growing RAM allocations without requiring huge numbers of memory slots or dozens of chips soldered onto the motherboard.

With DDR4 memory, a single RAM chip can typically store up to 2GB of information; since DIMMs normally use a maximum of eight chips per module, that means you won't normally see a DDR4 DIMM larger than 16GB. DDR5 lifts the bar right up to 8GB per chip, paving the way to storing 64GB on a single DIMM.

Then there's power management to consider. Older DDR3 DIMMs required a standard power supply of 1.5V, but DDR4 reduced this to 1.2V and DDR5 drops it further to 1.1V. You might wonder whether there's any point in reducing power consumption by a fraction of a volt: in practice, these changes don't translate to significant reductions in power consumption compared to the CPU and GPU. The actual amount of power consumed will, in any case, depend on how many chips are installed on the DIMM and how hard they're working.

However, just as with CPUs, lower voltages enable memory chips to run faster without overheating. This means manufacturers can set higher operating frequencies—and users can push things even further in order to squeeze out a little extra performance. That might sound like the type of technical sourcery that's best left to the experts, however, it's accessible to anyone thanks to a system called XMP.

THE MANY VARIETIES OF DDR

With multiple different standards, speeds, and timings available, you might be concerned about ordering the wrong RAM when it's time to think about an upgrade. However, you don't need to worry about accidentally damaging anything, because it's physically impossible to plug a DIMM into the wrong sort of slot.

Full-size DDR4 modules have 288 contacts along both sides of the bottom edge, with an off-center notch to ensure you can't plug them in backward. Although DDR5 has the same number of total contacts, the notch is in a slightly different place, so it's impossible to force a DDR4 module into a DDR5 slot, or vice versa. Much the same applies to the smaller SODIMMs used in laptops, which again have different pin counts and notches in different places.

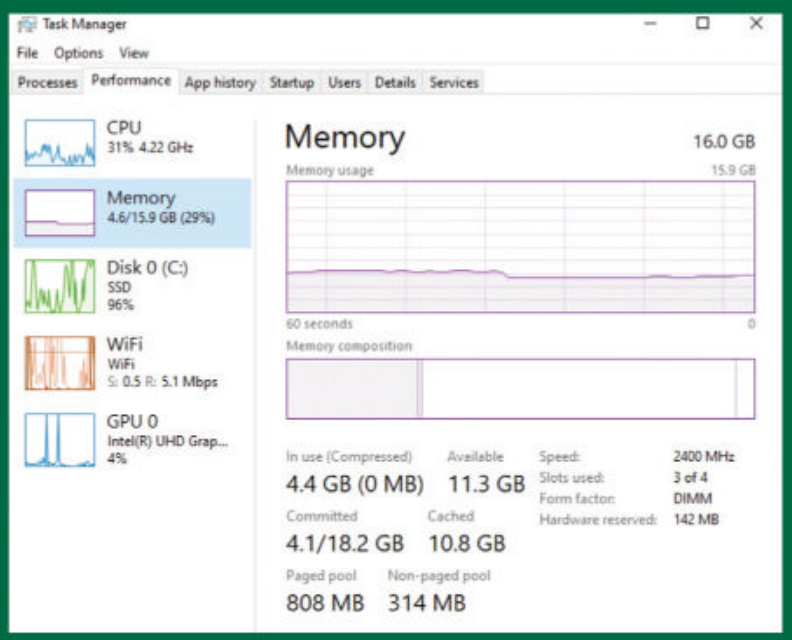
Laptops may use low-power DDR chips. The LPDDR4 and LPDDR5 standards aren't quite identical to their full-power counterparts and tend to run at lower speeds. This is largely academic, however, because you can't buy pluggable LPDDR modules anyway: the chips are designed to be mounted directly on a motherboard, which enables them to operate at voltages as low as 0.5V for LPDDR5.

HOW TO TEST YOUR RAM

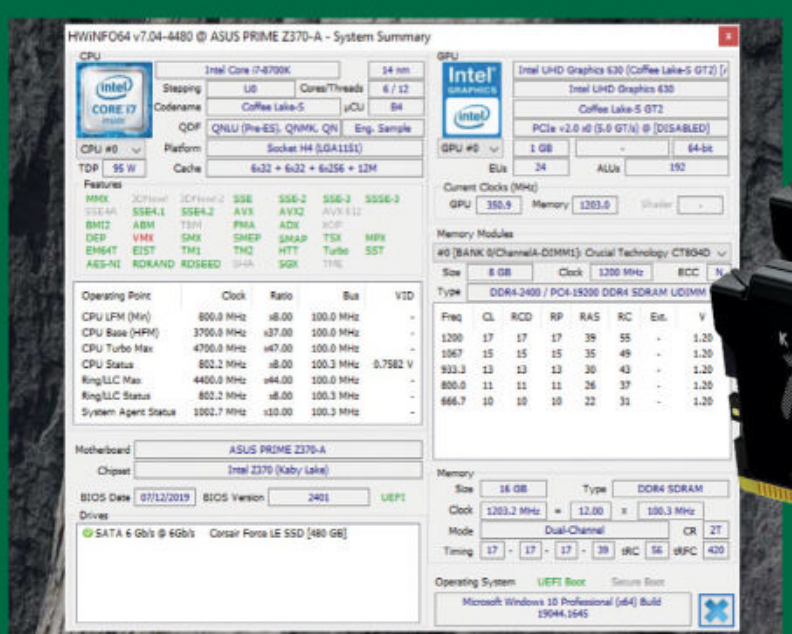
If you want to tweak the speeds and timings of your RAM, be prepared for plenty of trial and error, as it may not be immediately obvious if you've pushed too far. The odd single-bit glitch here and there might not have any noticeable effect until it happens in the middle of a system process and causes Windows to abruptly blue-screen. If you'd rather not find out the hard way, you can use Windows' built-in Memory Diagnostic tool to thoroughly test that your RAM is working as it should. Just open the Start menu and type its name to find it.

The catch is that, because this tool needs access to the full expanse of installed RAM, it has to run outside of Windows—you will need to reboot the system and wait for the test to complete before you can get back to the desktop. Depending on how much memory you have installed (and how fast it is) this can be a slow process; a wait of 30 minutes isn't uncommon.

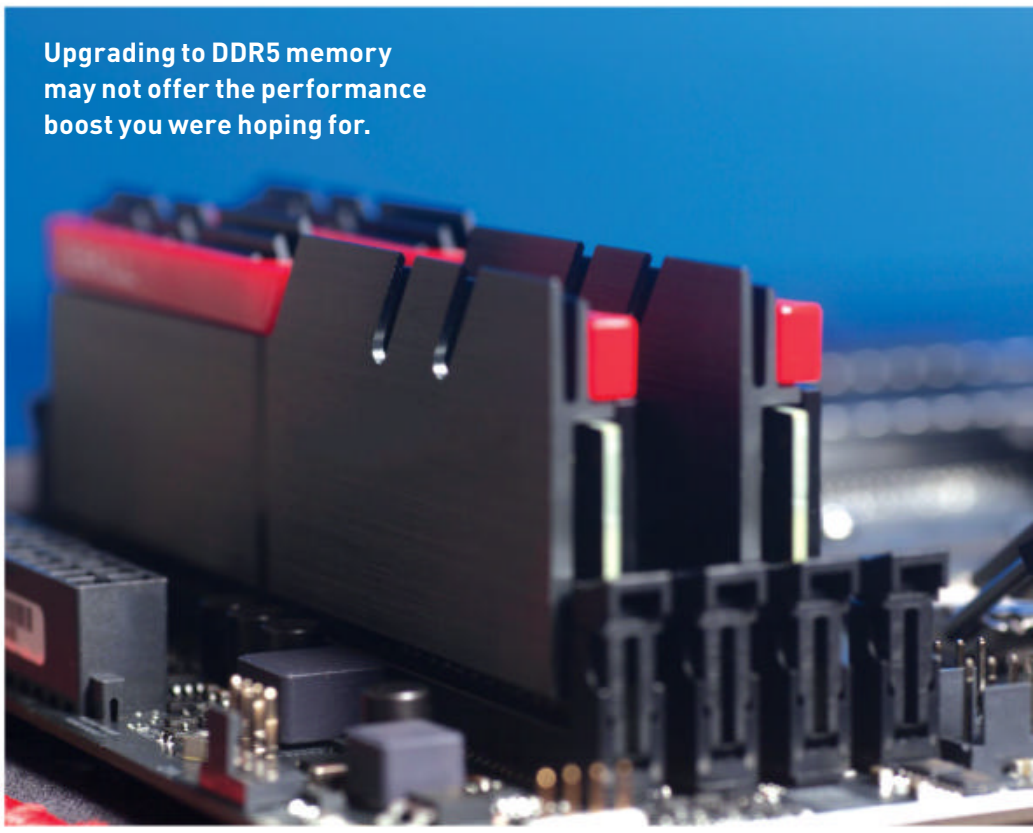
If you want an alternative that runs within Windows, check out HCI Design MemTest (free, hcidesign.com). Since this can only check areas of RAM that aren't reserved by the operating system, it can't test every location on every chip for hard errors, but it can help you get a quick sense of whether your RAM is stable or not.



Windows comes with tools to check your memory is working.



HWiNFO64 shows the timings and clock speeds of each DIMM.



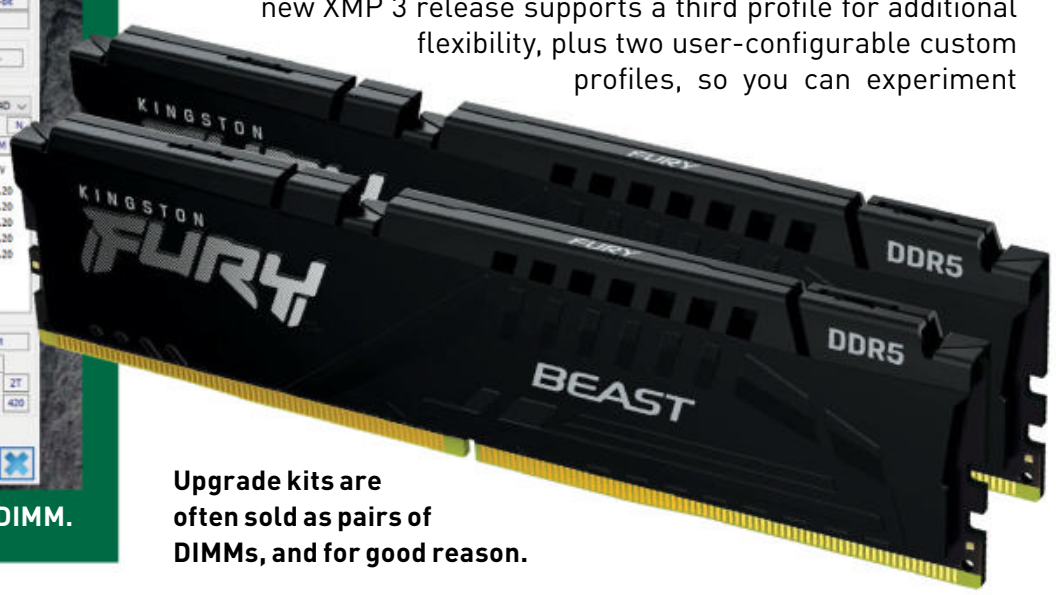
Upgrading to DDR5 memory may not offer the performance boost you were hoping for.

XMP FOR THEE AND ME

Every RAM module has its official frequency and timing specifications encoded into the hardware using a system called Serial Presence Detect, or SPD for short. But that doesn't necessarily mean that it is limited to those speeds. The BIOS settings will normally give you a free hand to increase the speed and dial down the latency as much as you dare. The catch is that if you push too far beyond the official specification, you'll start to get RAM errors, and sooner or later your whole system will most likely crash.

The XMP standard lets you overclock in relative safety: it allows memory manufacturers to embed additional profiles into their modules that go beyond the JEDEC-approved SPD values, to unlock the maximum speed that they're capable of. For example, a DDR5-5600 module would normally run at 2.8GHz, but the manufacturer might decide, based on its testing, to offer an XMP profile that dials up the frequency to a decidedly non-standard 2.95GHz. You can select this with some confidence, knowing that the chips should be capable of running stably at these speeds. A second more ambitious profile might also be included, which could require extra cooling to run reliably.

The XMP system was originally developed by Intel, but is now supported by a wide range of motherboards, even many AMD ones. And with DDR5, it gains an upgrade: while the XMP 2 standard used by DDR4 modules allows two profiles to be embedded, the new XMP 3 release supports a third profile for additional flexibility, plus two user-configurable custom profiles, so you can experiment



Upgrade kits are often sold as pairs of DIMMs, and for good reason.

© MICROSOFT, KINGSTON

with your own system and store the memory settings that work best for you.

If all that still sounds overly complicated, there's a way to make it even easier—just as long as you're using one of Intel's latest Core processors, that is. 12th-generation Alder Lake systems include a new feature called Dynamic Memory Boost, which switches automatically between XMP profiles, according to the workload. The RAM chips are overclocked when the system needs a burst of data, then allowed to slow and cool off when things quieten down. Neat.

There's one more thing that XMP takes care of. Memory modules running outside of the JEDEC standards may require a little extra power to keep them stable, and XMP profiles take care of telling the motherboard to set the voltage as needed to run at the specified frequency. If you want to try manually tweaking your RAM speed, this adds an extra dimension of complexity: a module may require a voltage boost to run stably at a particular speed, but this in turn will increase its cooling requirements.

DOING THE DOUBLE DOUBLE

One final factor that can affect RAM performance is whether it's running in a dual-channel configuration. That may sound odd, as all DIMMs are dual-channel by design — in other words, they behave like two separate memory modules working in parallel, offering double the bandwidth of the older single-channel SIMMs that were commonplace back in the days of Windows 95. On a modern motherboard, however, you can also install matching DIMMs in paired slots and run those in parallel, getting another two-fold increase in bandwidth. This is one reason why memory upgrade kits are often sold as pairs of DIMMs rather than as a single module (another is that lower capacities are generally more cost-effective to manufacture).

Both DDR4 and DDR5 can be provisioned in a dual-channel configuration, but DDR5 takes the idea further. Where DDR4 DIMMs use a single 64-bit data bus, DDR5 splits this into two 32-bit buses working together, so with matching modules you can take advantage of not two but three degrees of parallelism.

You can easily check whether your system is taking advantage of dual-channel RAM using a tool such as HWiNFO64. If it turns out that you're in single-channel mode, that normally means that your DIMMs aren't identical. If so, it's not a huge deal: dual-channel memory normally provides a real-world speed boost of less than five percent. If you're already using unmatched DIMMs, you'll probably see a bigger benefit from adding another one, rather than replacing existing modules to enable dual-channel operation.

HOW MUCH FASTER IS DDR5?

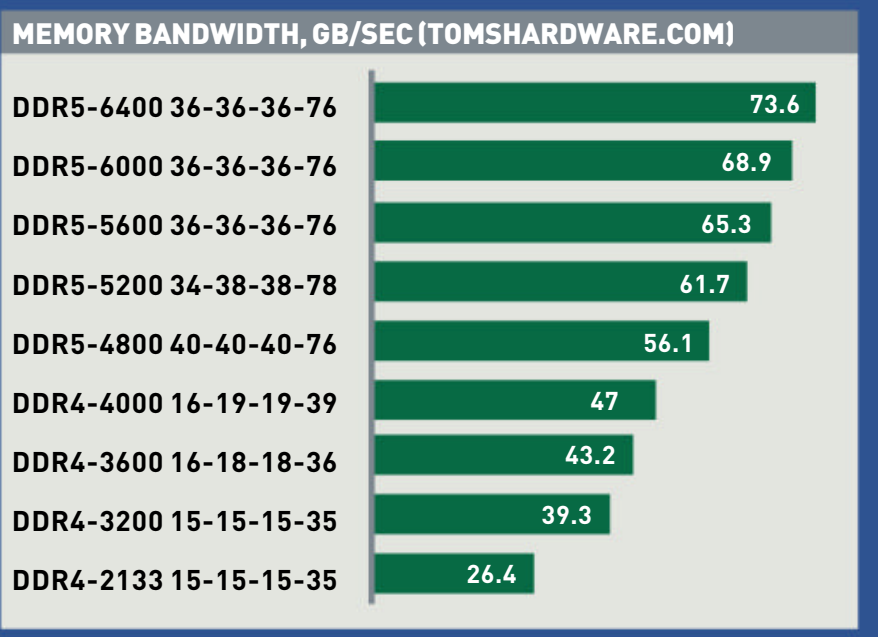
As you'll have gathered, it's impossible to say that DDR5 is x-percent faster than DDR4. Even two DDR4 modules can perform very differently. However, with a spread of tests, we can get a sense of the range of performance offered by the two RAM families. Our sister title *Tom's Hardware* recently did just this, carrying out a series of benchmarks on high-end modules running at different speeds, with their testers using the SiSoftware Sandra.

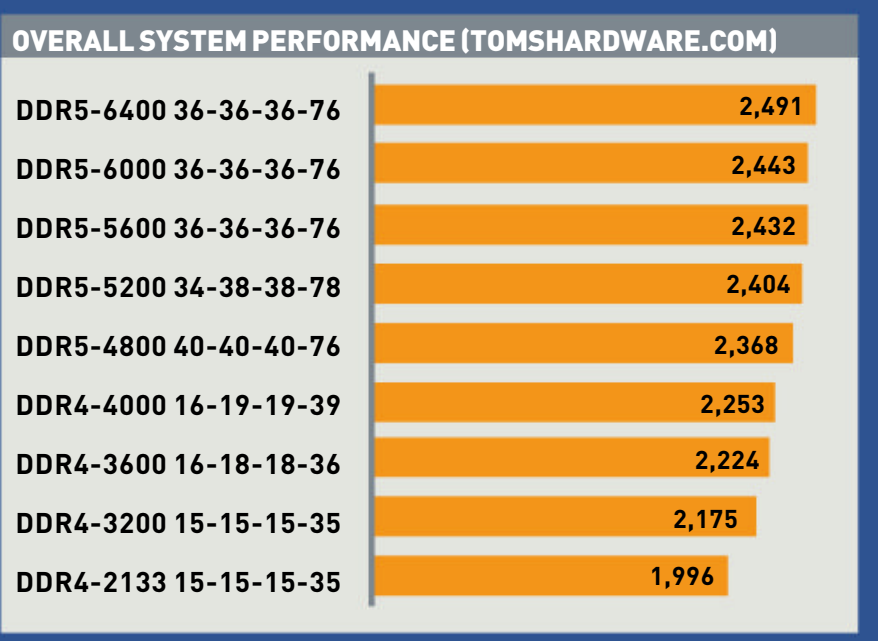
EVIDENTLY, DDR5 has a big technical advantage, with the faster frequencies directly translating into increased bandwidth. But before you ditch your DDR4 system, remember that everyday computing tasks may spend only a fraction of their time waiting for memory access. Since the timings for DDR5 are much higher than for DDR4, workflows that involve continually switching between RAM locations may see little benefit.

TO MEASURE real-world performance, *Tom's Hardware* carried out a separate set of tests using real-world applications such as Adobe Lightroom, Adobe Photoshop, Cinebench R23, HandBrake, and Microsoft Office. The graph here shows the overall performance scores that were calculated using the different memory types.

The actual performance benefit of DDR5 is nowhere near as pronounced as synthetic bandwidth comparisons suggest. While the fastest DDR5 supposedly offers nearly three times the bandwidth as the slowest DDR4 tested, the real-world margin was closer to 25 percent. For heavyweight data-processing tasks, a boost of that size is worth having. However, a single 16GB DDR5-6400 DIMM will currently set you back around $280, while a 16GB DDR4-2133 module can be had for $58, so whether it's worth the money is another question entirely.

For further details, visit: tinyurl.com/ddr5vddr4





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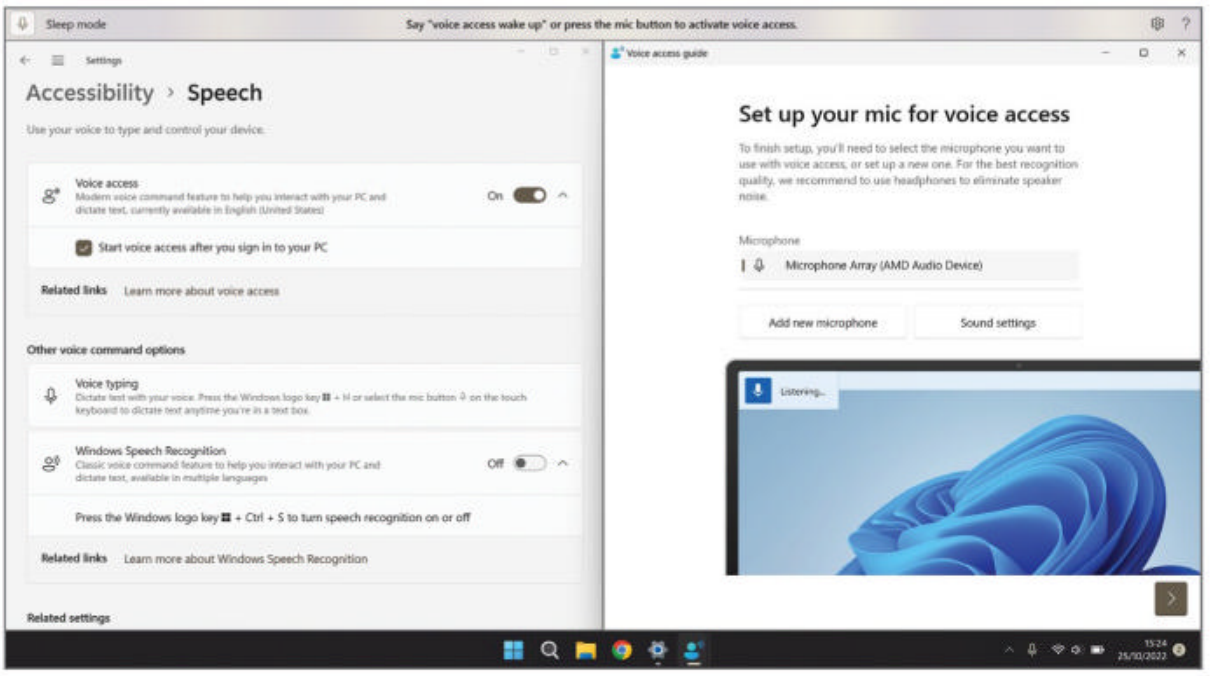


NAVIGATE WINDOWS 11 WITH YOUR VOICE

Apart from being incredibly useful, voice navigation is a nifty feature that can easily be enabled in Windows 11. Go to Settings → Accessibility → Speech (in the interactive section), and then toggle the Voice access switch to on. To get started, just say the words "Voice access wake up" and you're away. There is an interactive guide within the program too, so check that out to help you learn some of the most useful commands.

SAM LEWIS
STAFF WRITER

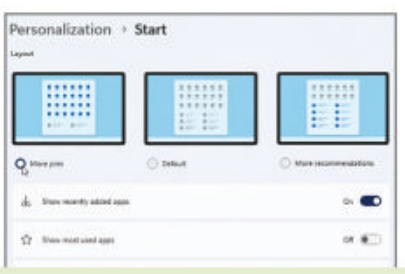
FROM DESKTOP TO HANDHELD?

It may seem like a strange time to buy an 11-year-old piece of tech, but that's exactly what I've done. A refurbished PS Vita came up for sale at a reasonable price online, and I decided to go for it. It's something I've wanted for a while, so I'm glad I managed to grab one.

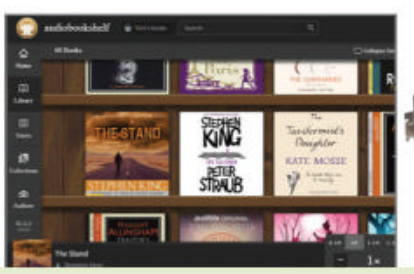
On paper, the Vita always had a lot going for it, but it came at the wrong time. With the likes of the Switch and the Steam Deck now dominating the handheld market, the Vita has had a big influence on this sector of the gaming world. This console came with two analog sticks—how I wished the PSP had that from the get-go. Sony was ahead of the mark, yet it never took off like the Nintendo 3DS, mainly due to its initial price and expensive memory cards. At the time of its release, an extra $50 could have gotten you a PS3.

I went in with an open mind and have been pleasantly surprised with this little device. The build quality still holds up today, especially the OLED model I opted for. I just needed a little handheld to pick up whenever I feel like a quick bit of gaming and this is perfect. It's a great way to experience some of my favorite PlayStation titles such as *Little Big Planet* and *Uncharted*. Sure, the games are a little pricey but they are more interesting than some triple-A releases of late.

MAKE – USE – CREATE



62
Windows 22H2 update: all new features explained.



66
Build an audiobook or podcast server.

70
Install and uninstall GPU drivers correctly.

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Under the hood of Windows 11 22H2

YOU'LL NEED THIS

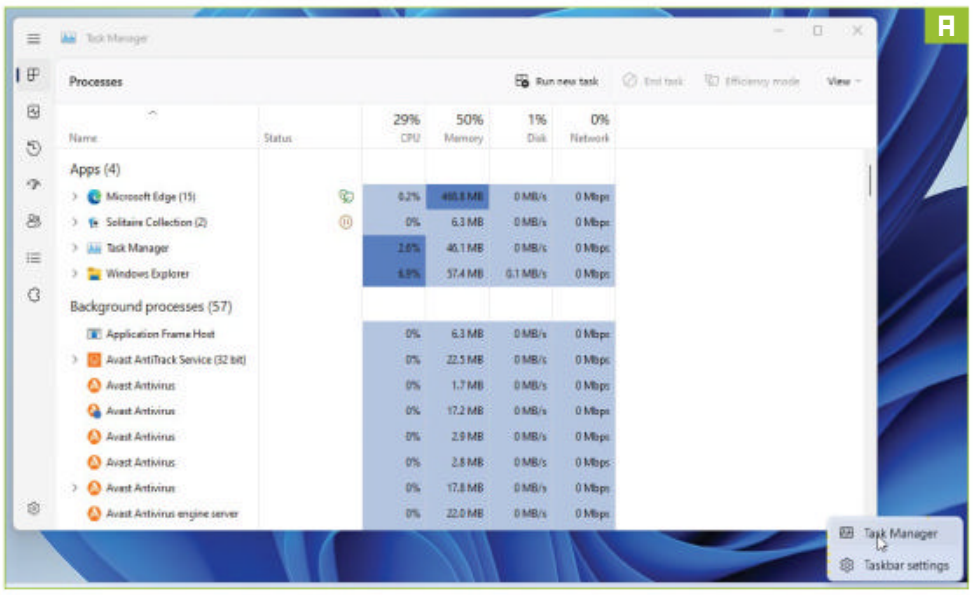
WINDOWS 11 AND THE 22H2 UPDATE

If you've not yet received it, check the box for troubleshooting tips, or email doctor@maximumpc.com.

THE FIRST MAJOR UPDATE TO WINDOWS 11, 22H2, is here, and with it, a whole new way of delivering future updates. In this month's tutorial, we're going to take you on a tour of all its major new features and a few minor ones, too. Crucially, though, we're not going to simply provide you with a list of what's new and improved and then leave you to find it all yourself. No, we'll show you exactly where to find each new feature and reveal how to make the most of it.

You'll discover how to make the best use of tabs in File Explorer, add live captions from any audio source (including your own microphone), plus discover some gaming enhancements to boost performance and make games easier to access. Focus Assist gets an overhaul to help improve your productivity by removing unwanted distractions for short bursts, and Task Manager finally gets an overdue facelift to fit in with the rest of Windows 11's redesign.

And all that's before we look at the incremental improvements the update brings to key features ranging from Snap Assist to the Start menu. Enough showboating, it's time to get down and dirty with Windows 11 22H2. –**NICK PEERS**



A

1 SHELL IMPROVEMENTS

Let's start our look at Windows 11 22H2 by acknowledging the ongoing process of streamlining and modernizing the Windows user interface—a seemingly endless process dating back to the launch of Windows 10. Press Alt + Win + K to reveal a new control for muting the mic during calls in supported apps in Teams. The redesigned flyout, which pops up above the taskbar, extends to other hardware controls such as volume and brightness—if your keyboard supports these, try them now.

›› The biggest beneficiary of this ongoing facelift is Task Manager [**Image A**]. If Task Manager isn't yet an option when right-clicking the taskbar, press Ctrl + Alt + Del and select 'Task Manager' to open it to the Process section. A series of buttons down the left replaces the tabs found on the old version—reveal their names via the ☰ button if the icons aren't self-explanatory.

›› You will also see some shortcut buttons within each section—'Run new task' is found on all sections, while others are context-sensitive (for example, Enable and Disable options for selected apps under Startup apps). Also, look out for the Settings button, where you can choose your default start page among other things.

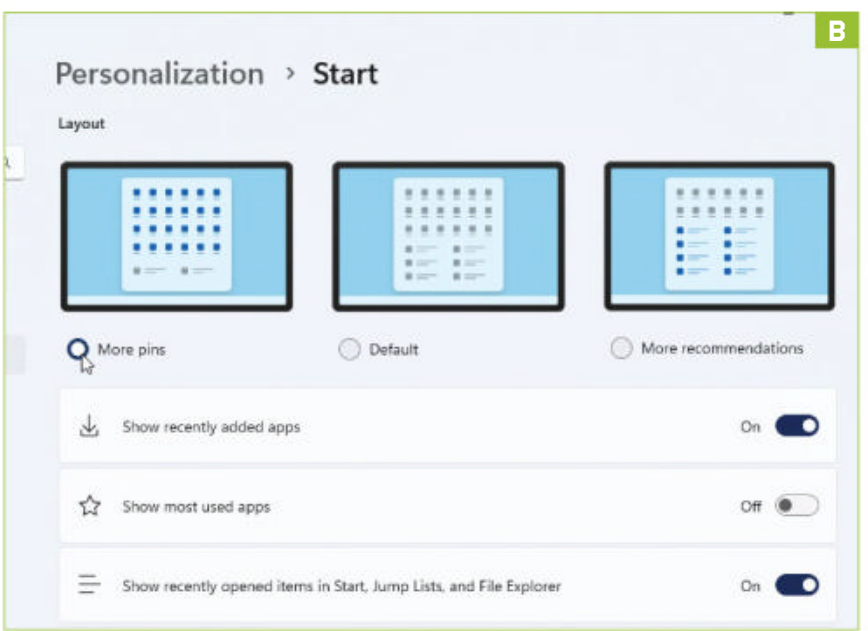
›› These design tweaks continue elsewhere throughout Windows, too—look out for subtle changes to icon designs in context menus or new folder preview icons when browsing user folders to help identify content inside. One specific example can be seen by right-clicking a file and choosing 'Open with → Choose another app'.

2 START MENU

We're still not convinced by Windows 11's lackluster Start menu, but the 22H2 update does introduce a couple of minor improvements. Ironically, these mainly restore features stripped from the Windows 10 Start menu, such as the ability to create app folders inside which related items can be nested, for example, plus the ability to adjust the relative sizes of the pinned and recommended app sections.

›› To change the latter, right-click on any blank space on the Start menu and choose 'Start settings' to be whisked off to Settings → Personalization → Start. Here you'll see three thumbnails—the Default setting gives both pins and recommendations equal space, but you can easily switch them to give either one or the other prominence [**Image B**].

›› When it comes to grouping apps into folders, simply drag one app icon within the Pinned section onto another to group them together, then click the folder followed by



B

'Edit Name' to rename it. You can drag other apps into this folder in the same way or open the folder and drag an app icon out of it to remove it.

›› Speaking of apps, you'll notice some name changes under All Apps: Terminal (instead of Windows Terminal), Windows Media Player Legacy, and Accessibility instead of 'Windows Easy of Access'. Similarly, right-clicking the Start button reveals 'Apps & Features' is now labeled 'Installed apps'.

›› One other change is that you can now quickly change the way you sign into Windows by right-clicking the power button on the Start menu, where you'll find a new 'Sign-in options' shortcut to the relevant area (Accounts → Sign-in options) of Settings.

3 TASKBAR IMPROVEMENTS

The taskbar also regains some useful functionality. By now, you should hopefully see 'Task Manager' appear when right-clicking it as a useful shortcut. A new feature sees an overflow (...) button appear if you've filled up the taskbar with icons (pinned or otherwise). Click this to reveal all hidden items. Adding pinned items to the taskbar from the Start menu has also gotten easier—simply expand 'All apps' and drag your chosen shortcut onto the taskbar to pin it as a link.

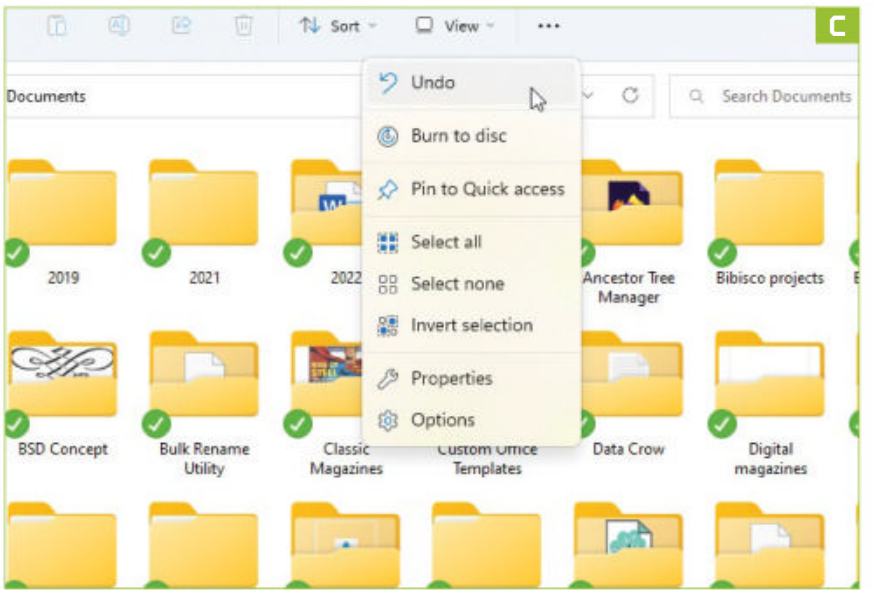
›› Another restored feature lets you drag a file onto an open app's icon on the taskbar. Wait for the app window to pop up and then simply drag the file where it needs to go to open it in that application.

›› Here's a handy shortcut. Want to quickly change the system volume? Place the mouse pointer over the taskbar notification area's quick settings button (the one combining network, audio, and, if applicable, power icons), and you can then use the scroll wheel to increase (scroll up) or decrease (scroll down) the volume as required.

›› There are also a few minor changes when you click the button to open the Quick Settings flyout. You'll see that the Bluetooth button gains an expanded (→) button—clicking this allows you to access Bluetooth-connected devices and pair with others, just as the Wi-Fi button allows you to switch networks. One feature conspicuous by its absence from Quick Settings is the Focus assist button, but more on that shortly.

4 FILE EXPLORER TABS

Obviously, the huge new feature in File Explorer is support for tabs [**Image C**]. At last, no more cluttering your desktop with two or more separate windows; instead, use the tab bar at the top of the File Explorer window to group related folders together. Click + or press Ctrl + T to open a new tab, then simply browse to where you want it to point. From here, you can drag files and folders onto a tab to bring that tab into focus before dropping the file where you want it to go (don't forget the usual rules surrounding moving and copying—hold Ctrl to force the file to copy or Shift to force it to move if you're not sure).



›› You'll be pleased to learn that tabs work in the same way as in Edge: you can click and drag tabs to rearrange them, close the tab via the 'x' button, or right-click a tab for more options, including closing all other tabs or simply those to the right of the currently selected tab.

5 FILE EXPLORER NAVIGATION

File Explorer's other major change can be seen in the Navigation pane on the left. It has been reorganized into three primary sections: Home and OneDrive sit at the top, pinned and frequently accessed folders are located in the middle section, and beneath this are other views: My PC, external drives, your network, other linked cloud folders (such as Nextcloud), and so on.

›› The Home folder is basically a revamp of the old Quick Access view. It comprises three collapsible sections: Quick access, Favorites, and Recent. These are all largely self-explanatory—Quick Access mirrors what's shown in the left-hand navigation pane, while Favorites is a new section where you can pin your frequently accessed files. Simply right-click a file and choose 'Add to Favorites' to pin it. Right-click the Home folder in the navigation pane and you can also pin it to your taskbar or Start menu for easy access.

WHITHER 22H2?

By now, your PC should have offered you the latest feature update, but if for any reason Windows Update still hasn't made it available, then you need to determine whether there's a setting or device on your PC that might be blocking the update.

Start by searching for PowerShell, then click the 'Run as Administrator' option that appears beneath it. Now enter the following command:

```
Install-Module FU.WhyAmIBlocked
-Scope CurrentUser
```

You'll be prompted to install the NuGet repository, press Y, and hit Enter twice when prompted. Once done, type the following command to adjust your PC's script policy:

```
Set-ExecutionPolicy -ExecutionPolicy
Unrestricted
```

Again, press Y when prompted. Now type the following two commands:

```
Import-Module FU.WhyAmIBlocked
Get-FUBlocks
```

Once the scan is complete, you'll hopefully be told no blocks exist.

If this is the case, attempt to install the 22H2 update using the Windows Installation Assistant (www.microsoft.com/software-download/windows11)—we would recommend running the installer with administrative privileges.

If there are blocks, review the text file generated and Google to see what remedies there may be. For example, temporarily disabling Windows Hello as a form of logon or removing certain printer drivers.

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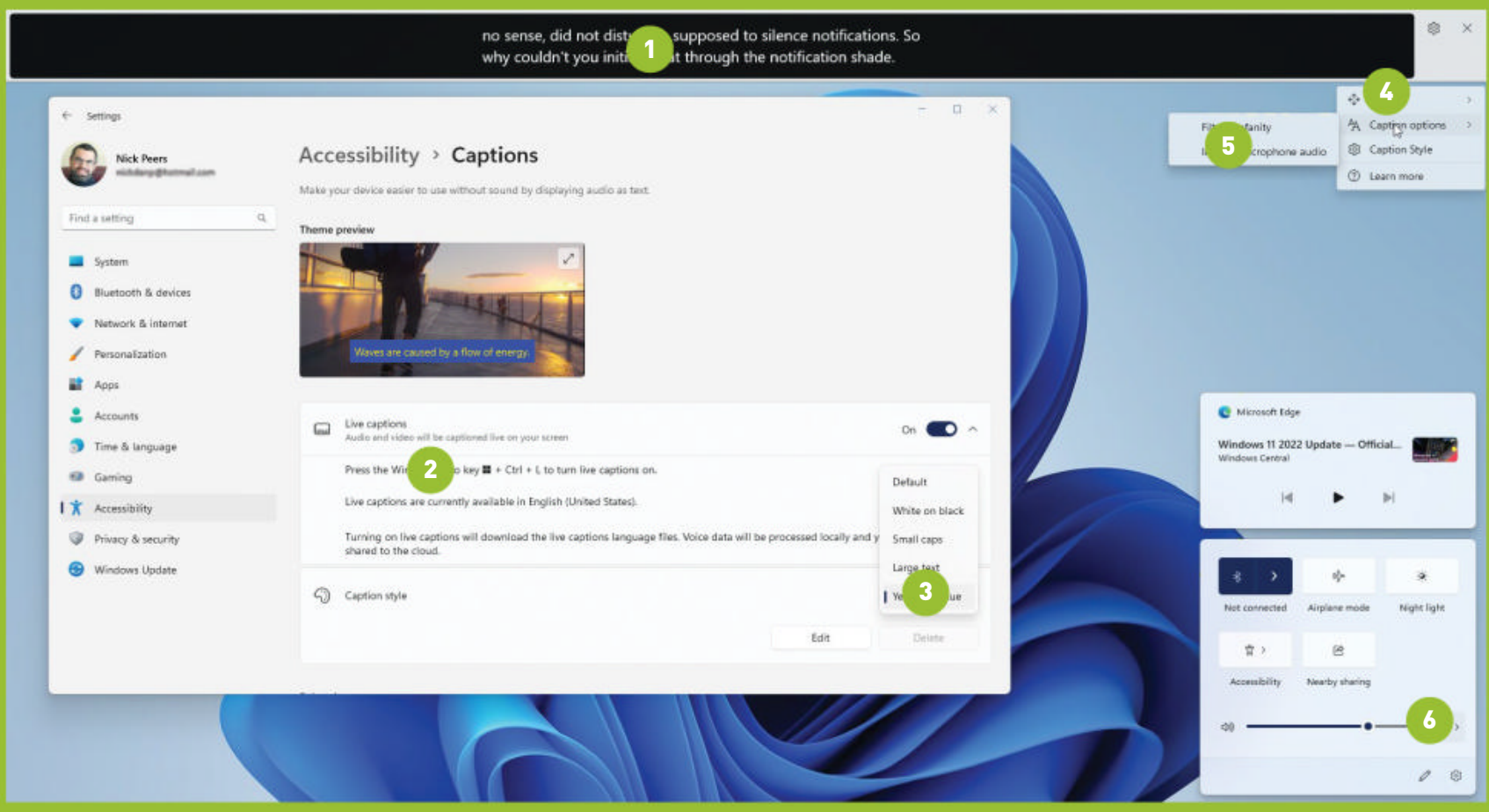
LIVE CAPTIONS



1. LIVE CAPTIONS PANEL
By default, the Live Captions panel sits at the top of the screen. The first time you open it, you'll be prompted to download the processing software required.

2. ENABLE LIVE CAPTIONS
If you prefer, you can toggle Live Captions on or off via Settings → Accessibility → Captions, but it's far easier to learn its keyboard shortcut: Ctrl + Win + L.

3. CAPTION STYLE
Don't like the caption's font, style, or color? Then there's a handy dropdown menu offering you five quickfire choices; alternatively, click Edit to set up your own style from scratch.

4. CAPTION POSITION
Choose Settings → Position should you wish to either place your captions at the bottom of the screen or have them in a floating semi-translucent window that sits on top of other windows.

5. CAPTION OPTIONS
Make your captions family-friendly by enabling the profanity filter. If you are presenting to others, choose 'Include microphone audio' to provide real-time closed captions as you speak.

6. SWITCH SOUND DEVICE
If you have multiple sound outputs on your system, open the Quick Edit panel via the taskbar notification area to switch outputs via this button if required.

›› One final tip: when browsing the Recent list in Home, look for the Filter button in File Explorer's taskbar: click this to show only those file types you're interested in.

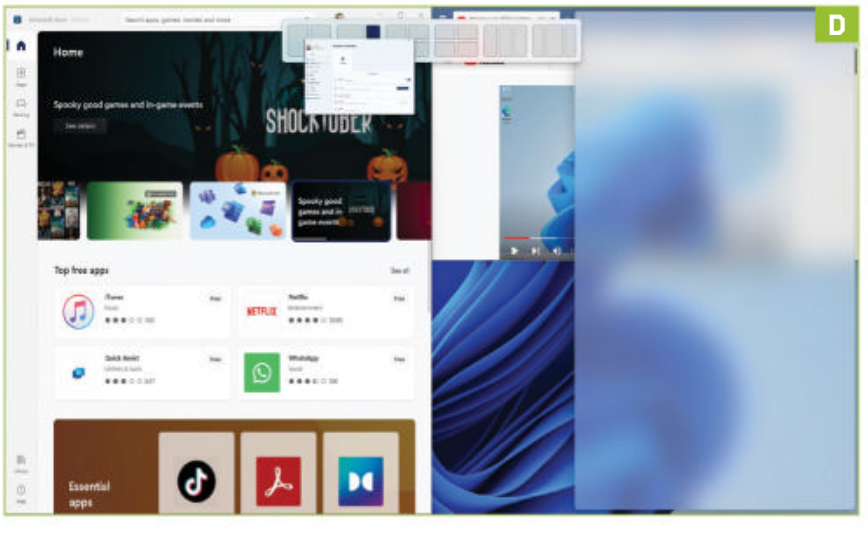
›› Elsewhere, you'll see subtle changes to some of the pop-up menus—right-click This PC to reveal more options for adding network locations, for example, while an additional 'Connect to a media server' option appears when clicking the '...' menu in This PC view. Also, note the redesigned icons we mentioned earlier when displaying a folder's contents as large or medium icons.

6 A NEW FOCUS

Another tool undergoing a name change is Focus (formerly Focus Assist). This isn't just a cosmetic change, it has been moved from Quick Settings to reside under the pop-up calendar that appears underneath Notifications when you click the date and time in the taskbar notification area. Beneath the calendar, you'll see a button for enabling Focus along with controls for determining how long you want it to run.

›› There are also changes to how Focus is configured. Navigate to Settings → System and you'll find the Focus section concentrates on providing universal options: the session duration, whether the clock app shows a timer and a 'do not disturb' setting, alongside options for hiding flashing and badges on taskbar apps.

›› Beneath this is a Notifications shortcut. This reveals where the automatic rules have migrated to, namely System → Notifications. Here, you can configure 'do not disturb' and choose priority notifications and other apps that you're happy to provide updates during a session.



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7 GAMING IMPROVEMENTS

Windows 11 is keen to enhance its gaming credentials, and the 22H2 upgrade delivers some welcome improvements. If you have an Xbox controller or similar, pressing the Xbox button on your controller pops up a new Controller bar providing a convenient shortcut to access both game launchers and recently played games.

» Gamers can now enjoy DirectX 10/11 display latency improvements when playing games in windowed mode as well as full-screen. Enable this feature via 'Settings → System→ Display → Graphics → Change default graphics settings'. Other features extended to windowed mode include support for automatic HDR and variable refresh rate (VRR). Speaking of HDR, there's a new HDR Calibration app to help boost the color accuracy and consistency of your HDR-capable display.

» If you've set up a webcam for video conferencing or gaming, you'll be pleased to learn that the 22H2 update rolls out new audio and video configuration options via 'Settings → Bluetooth & devices → Cameras'. If your camera supports it, look out for a new Camera Effects section, offering such features as background blur, automatic framing, eye contact, and a separate voice focus option, which attempts to filter out background noise.

8 WINDOWS MANAGEMENT

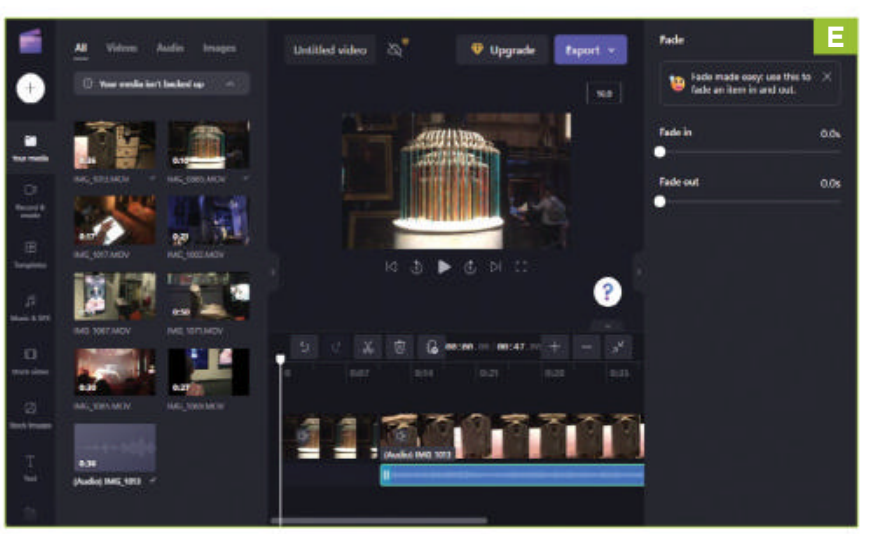
Windows 11 delivers further improvements in two key areas of application and window management: Snap Assist and Task View. Start dragging a window and you'll see the bottom of the Snap Assist window peek out from the top of the screen. Drag your window here to access six different layout types supporting up to four windows.

» Simply drag your window into one of the windows [**Image D**] and a blurred preview of where the window will appear on-screen is shown. Let the mouse button go and the selected window will be resized and shaped accordingly. You'll see the remaining applications appear in one of the other windows—click one to place it here, then move on to the next to create a snap group, or simply click inside the main application to leave all other windows as they currently stand.

» Snap groups come into play when switching between application windows using the Win + Tab key or Task View button on the taskbar. In addition to individual application windows, you'll now be given an opportunity to switch to a different snap group too. Another related change is that the Alt + Tab switcher now displays each app in its own windowed interface.

9 AND THERE'S MORE...

Those changes keep on coming. A feature slowly rolling out from the October 'Moments' update is Suggested Actions. When you copy a date, time, or phone number, Windows will pop up a suggested actions panel with relevant options, such as opening certain apps, calling the number, or creating a calendar event from a copied date.

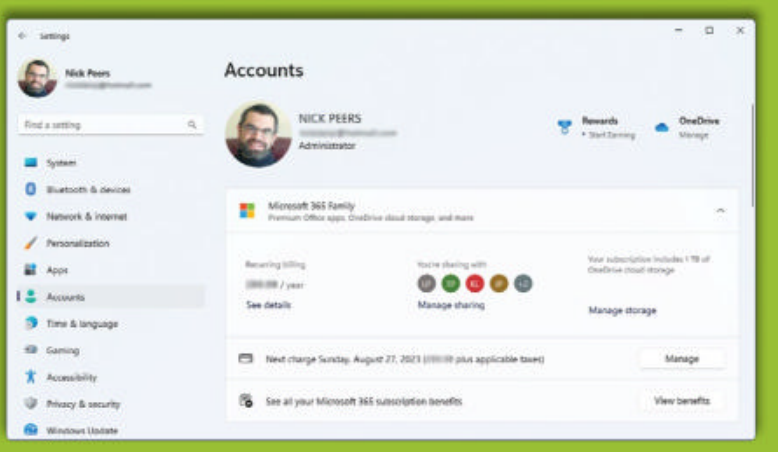


» Windows 11 22H2 also bundles two new apps: ClipChamp for video editing [**Image E**] and a new version of Sound Recorder titled Voice Recorder. Other bundled apps also get updates, but these require installing through the store—they include Photos, which adds support for directly uploading photos to OneDrive and a new curated Memories feature, plus Microsoft Family Safety (which drops the 'Safety' from its name).

» Look out too for the new Smart App Control tool, accessible through the 'App & browser control' section of Windows Security. Sadly, this feature is only available via clean installs of Windows 11, but if enabled, could help you avoid malicious and potentially unwanted apps through careful monitoring of their behavior.

» Last, but not least, is Live Captions. These enable you to generate closed captions on the fly for any audio (or video) file currently playing. They're currently restricted to English-language audio, but all processing is done locally, so there are no security ramifications involving sending your files to the cloud. You can even use Live Captions to generate captions when speaking into your mic—see the annotation for more details of what it offers.

FEATURE PACKS



The Windows 11 22H2 update opens with a major cultural shift. You'll have noticed this if, after first updating, you discovered the long-awaited tabs in File Explorer were missing because Microsoft held the feature back. That's the bad news; the good news is you won't have to wait 12 months for it to finally appear in 23H2. That's because Microsoft has unveiled a new way of rolling out feature updates.

It was quick to demonstrate this new approach when it announced the first of these so-called 'Moments' on 18th October. Not only were tabs finally implemented, but additional improvements also saw the return of the 'Task Manager' option to the Taskbar's context menu as well as additions to the Accounts section under Settings, like the ability to review and manage your Microsoft 365 account.

Annoyingly, these features may not appear all at once; for example, support for tabs and pinning files in File Explorer appeared in the 18th October out-of-band update, while the new Accounts feature turned up a week later in the 25th October update. We saw the Accounts feature appear first after finally updating to 22H2 on 30th October—the File Explorer improvements rolled up the following day after installing the October Cumulative Update.

Build a Streaming Audiobook Server

YOU'LL NEED THIS

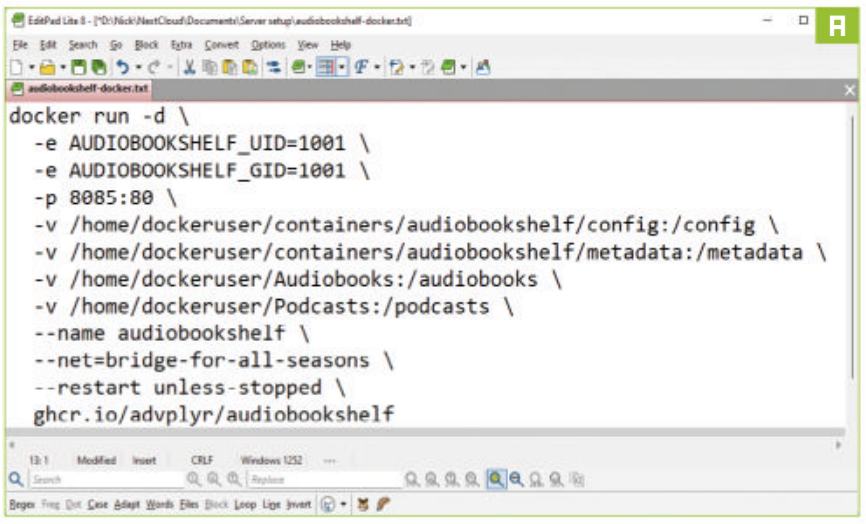
A PC OR SERVER RUNNING UBUNTU, DEBIAN OR DOCKER
plus Audiobookshelf and a collection of digital audiobooks

IF YOU LOVE LISTENING to audiobooks, you may have accumulated a huge pile of CDs over the years or amassed an Audible library to be proud of. But why not convert those audiobooks into your own personal streaming library, hosted on your server and open to all your friends and family? Building such a library has traditionally been challenging—some have attempted to incorporate audiobooks into existing media servers such as Plex, while dedicated audiobook servers have been thin on the ground.

Until recently, there was one practical choice for standalone audiobook streaming, and that was Booksonic (https://booksonic.org/). But in the space of a year, Audiobookshelf (www.audiobookshelf.org) has swooped in, offering a powerful, yet user-friendly server to give audiobooks (and podcasts) the streaming platform they deserve.

Audiobookshelf is available as a standalone tool for Linux—most notably Ubuntu and Debian—but it also ships as a docker instance, which makes it the perfect candidate for adding to a server PC, such as the one we built in our September 2022 issue.

In this tutorial, then, we'll run you through installing Audiobookshelf through docker, reveal how to get your audiobook server up and running, plus make it accessible to friends and family via the medium of any major phone, tablet, or computer. **–NICK PEERS**



1 SET UP YOUR FOLDERS

If you're not familiar with docker, start by checking out the four-page tutorial in the October 2022 issue of *Maximum PC*. There, we set up a dedicated 'dockeruser' user for security purposes, and we'll be using that user for this tutorial. Let's start by setting up any required folders. Assuming you followed our September 2022 build feature, you'll be accessing your server through the cockpit web interface. Log into your dockeruser account, select Terminal in the left-hand pane, and issue the following commands:

```
cd containers
mkdir audiobookshelf
```

›› This creates the /home/dockeruser/containers/audiobookshelf folder, which is where your Audiobookshelf settings will reside. Now create two more subfolders inside here:

```
cd audiobookshelf
mkdir config metadata
```

›› You don't need to transfer any actual audiobooks or podcasts into this folder—they can be stored elsewhere on your system if you prefer. In our example, we'll be storing them in separate folders within dockeruser's home folder. If you're wondering where you can source your audiobooks from, check out the sidebar on page 69.

2 INSTALL AUDIOBOOKSHELF

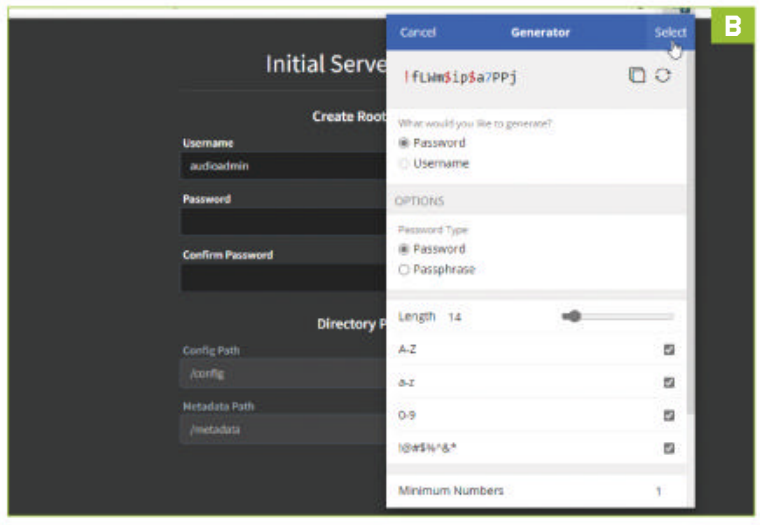
Next, open a text editor on your main PC and add the lines

```
docker run -d \
  -e AUDIOBOOKSHELF_UID=1001 \
  -e AUDIOBOOKSHELF_GID=998 \
  -p 8085:80 \
  -v /home/dockeruser/containers/audiobookshelf/config:/config \
  -v /home/dockeruser/containers/audiobookshelf/metadata:/metadata \
  -v /home/dockeruser/Audiobooks:/audiobooks \
  -v /home/dockeruser/Podcasts:/podcasts \
  --name audiobookshelf \
  --net=bridge-for-all-seasons \
  --restart unless-stopped \
  ghcr.io/advplyr/audiobookshelf
```

as shown in [**Image A**]. These need adapting to your setup. Use the 'id' command in cockpit's Terminal to determine the correct UID and GID values for the dockeruser:

```
id dockeruser
```

›› Next, Audiobookshelf communicates on port 80 by default. This is likely to clash with other services running



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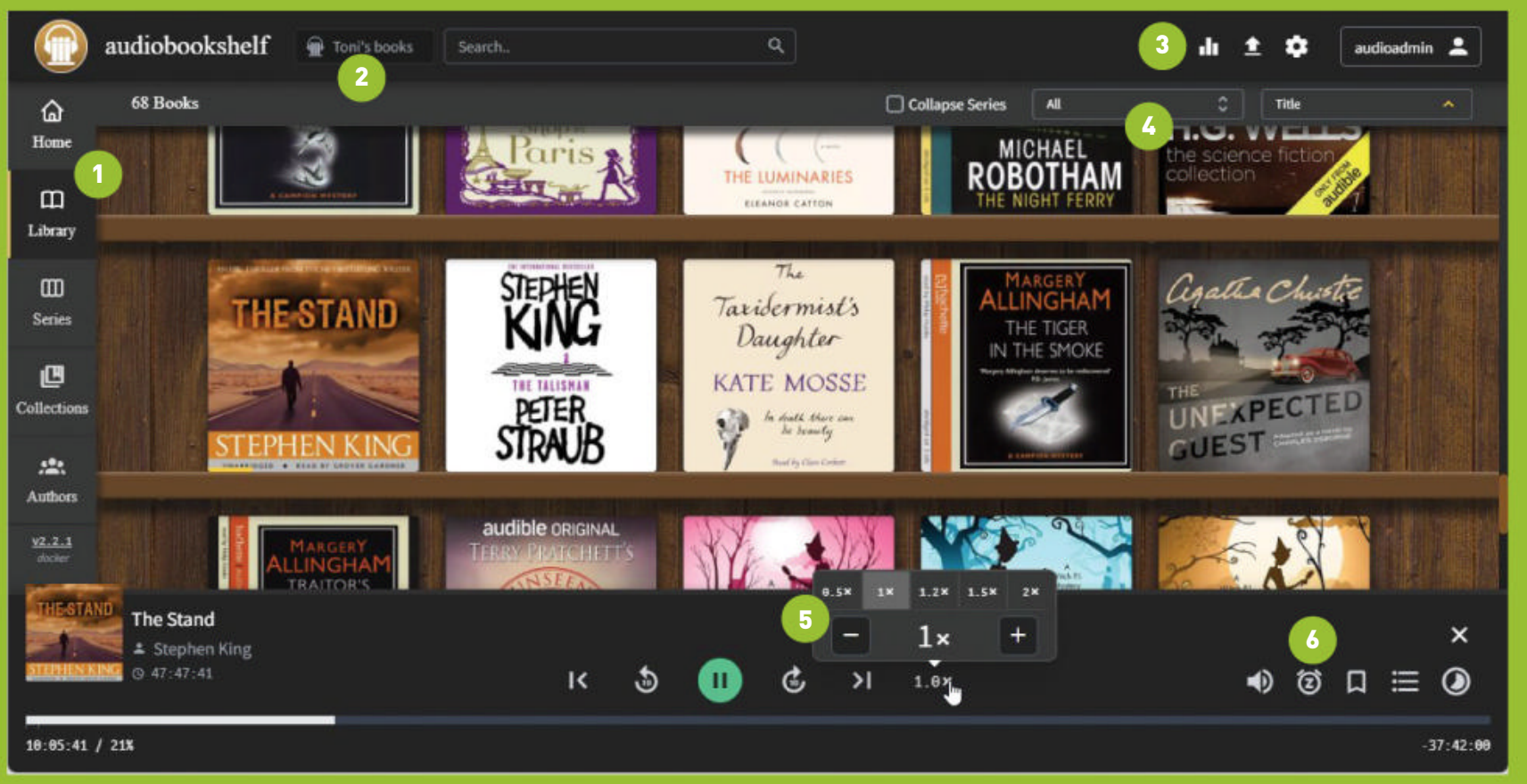
THE AUDIOBOOKSHELF INTERFACE



1. NAVIGATION
The Home view shows recently added and played material. Switch to Library for the view shown here, with additional views (Series and Collections) available alongside a list of authors.

2. SWITCH LIBRARY
If you have more than one library configured, click here to switch between them. Libraries are self-contained and isolated from each other.

3. VIEW STATS
Click the graph button to access key stats about your library, including insights into who's listening to what. The upload button next to it allows you to quickly add new content to your library.

4. FILTER VIEW
Use the 'Title' dropdown to change the way your library is sorted, author is a popular alternative. Click 'All' to apply various filters to the view.

5. AUDIOBOOK PLAYER
You can stream audiobooks directly from your browser window. Once playing, you'll find an array of available playback controls, including the ability to change the playback speed.

6. SLEEP TIMER
Click the alarm clock button to set a sleep timer, which will pause playback. Click to amend the time (add 30 minutes with one click) or cancel the countdown.

on your server, so modify the -p line if port 8085 is already being used by another service.

›› Beneath this, you need to amend each -v line to point to the relevant folders—the config and metadata folders you created in the last step, plus whichever folders you've stored your audiobooks and podcasts in.

›› The --net line is for those who have set up a reverse proxy following the October 2022 docker tutorial. If you have no plans to access your audiobook server outside of your local network you can remove the line entirely; otherwise, make sure 'bridge-for-all-seasons' matches the same network bridge assigned to your reverse proxy.

›› Once you've adapted the docker command, save the text file on your main PC for reference and then press Ctrl + A followed by Ctrl + C to copy it to the clipboard in its entirety. Now switch back to cockpit's Terminal to download the latest version of Audiobookshelf:

```
docker pull ghcr.io/advplyr/audiobookshelf
```

›› Once all the files have been downloaded and extracted, press Shift + Insert, which should paste the clipboard's contents into the Terminal. Hit Enter to create and start your new Audiobookshelf instance.

›› Wait around 30 seconds, then type the following into your web browser: http://192.168.x.y:8085/, substituting 192.168.x.y with your server's IP address and 8085 with whichever port you chose for the -p line in the previous step. If all is working as it should be, you'll be met by an 'Initial Server Setup' screen where you'll be invited to create the root user. For security's sake it's a good idea to choose a different username to the 'root' presented to you, so change this and then set up a suitable password [**Image B**] before clicking Submit.

3 CREATE FIRST LIBRARY

The user will be set up and you'll immediately be asked to log in using the credentials you just created. Then you'll find yourself being whisked off to the Libraries section of Audiobookshelf's Configuration, ready to add your first library.

›› Click 'Add your first library'. You'll be prompted to set the media type (books or podcasts) and give your library a suitable name. Each library can be assigned one of six icons, then set a default metadata provider, which will provide the information to flesh out the library with information like a description, narrator, and year. Google Books is the default, but there are alternatives: Open Library (https://openlibrary.org/), iTunes, and various regional Audible databases [**Image C**].

PREP YOUR FILES

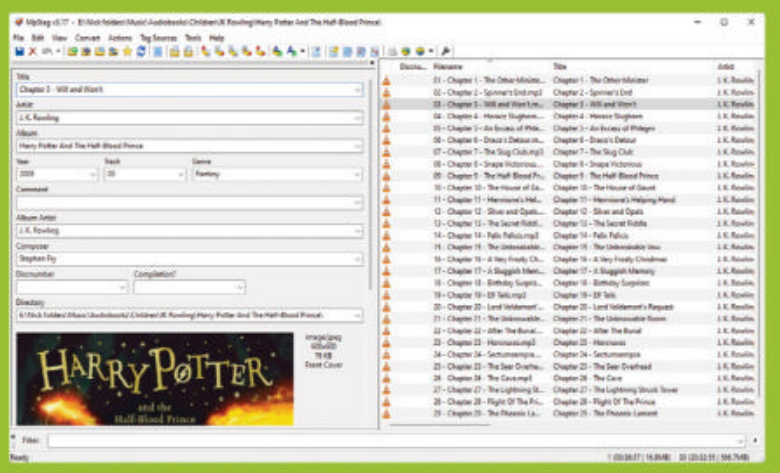
Like all good media servers, Audiobookshelf can do the hard work of locating metadata and covers for your audiobook collection based on how you organize your files. The basic folder structure is this:

Author → Series → Title → files

You can skip both Series and Title folders if you wish and simply store audiobook files in the Author directory—the name of the file is considered the name of the book. However, many audiobooks are split across multiple files, so storing these inside separate Title folders makes sense in these circumstances.

The Author folder supports various naming types from First Last (such as Stephen King) to Last, First (King, Stephen), and Title folders can be named in various ways too—navigate to www.audiobookshelf.org/docs/ and select 'Directory Structure' under Books for details.

If you've previously gone to great lengths to tag your files using ID3 metadata, then Audiobookshelf can recognize these too, including embedded cover images. If you'd like to continue this practice, then I recommend using MP3Tag (www.mp3tag.de/en/) for embedding key information, plus Booksonic Library Editor (https://github.com/galacticat/booksonic-library-editor) for adding additional metadata such as narrator, book synopsis and cover image in the form of text files (desc.txt and reader.txt) that are also recognized. Details of how to map ID3 tags (such as artist and album artist to author) are listed in the 'Audio Metadata' section under Books.



Use MP3tag to embed metadata into audiobook files.

›› Finally, click Browse for Folder. Click audiobooks or podcasts and you should see it's mapped to the relevant folders on your server's hard drive. If your audiobooks reside in several different folders, say one for each member of your household, you could either create separate libraries for each folder or combine multiple folders in a single library (after highlighting your first parent folder, click 'Select Folder Path' and then click 'Browse for Folder' again to select another). Choosing separate libraries works best if you plan to share your audiobook server with others as you can restrict access to libraries on a user-by-user basis, as we'll see later.

›› Before clicking 'Create New Library', explore the Settings and Schedule tabs. By default, you'll see Audiobookshelf uses 'square' book covers to mimic audiobook CDs when displaying titles in your library, but you can revert to a traditional book cover (1.6:1) aspect ratio if you prefer. The 'folder watcher' option ensures that any titles you add to the library should be automatically added while Audiobookshelf is running. If you disable this, use the Schedule tab to set up an automatic scan at regular intervals. The final two options allow you to skip matching any books with metadata already supplying an ASIN (Amazon) or ISBN as these will simply use those unique identifiers to look for metadata to download. Once you're happy with your settings and choices, click 'Create New Library'.

4 EXPLORE YOUR LIBRARY

The library will be created almost instantly; next, you need to scan it. You can do this from the Settings → Library screen by rolling your mouse over your new library to reveal a green Scan button, or you can return to the main Audiobookshelf screen (click the logo in the top left corner) where you'll be shown the main library screen. It tells you it's empty—click 'Scan Library' and you'll see various pop-up notifications appear telling you the scan has started, and when it's completed.

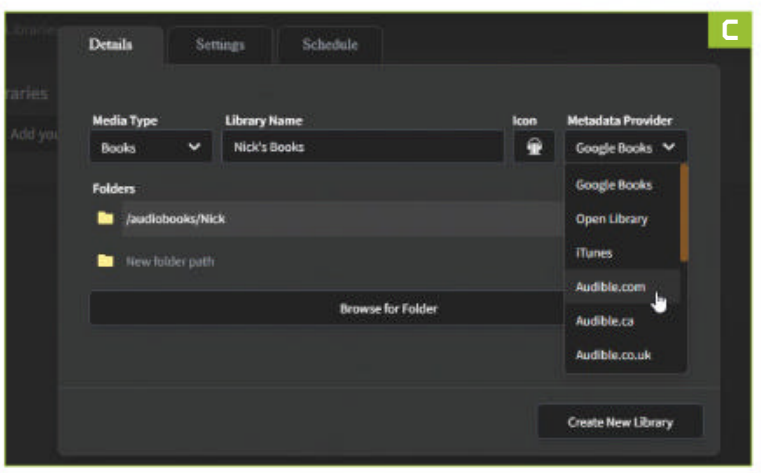
›› The Home library view will now appear showing you the books it's found, divided into two sections: Recently Added and New Authors. Other views include Library, which provides you with a complete list of books in your library. By default, books are displayed in title order, click the drop-down menu on the far right to choose a different sort order, with options including author or date published. Next to this is an 'All' dropdown menu, providing you with a wide range of filters to apply, including genre, tag, authors, and narrator.

›› Beneath Library are Series and Collection views, which show any titles you've arranged into series or collections, while at the bottom is Authors, allowing you to browse your library by author.

5 EDIT METADATA

Now it's time to fill in some of the gaps in your books' metadata. The initial scan should have populated most of your database's fields—author and title, but also description, narrator, and other pertinent information. Roll your mouse over a book's title's thumbnail and look for the pencil icon in the top right corner. Click this to open a Details pane with information spread across multiple tabs.

›› Some information should be prefilled, based on the filename and folder structure, but other details may be missing. While it's tempting to use the Quick Match button to try and populate this information, instead switch to the Match tab. A search with your library's default provider will be performed; if no results are found, you can tweak the search title and author or choose a different provider from the dropdown menu and click Search again.



© MP3TAG, AUDIOBOOKS

» With a bit of luck, you'll see a straight match appear among the list of results. To apply this metadata to your audiobook, just click the result and you'll be shown a summary of what changes will be applied, including any cover images if found. Scroll down and click Update to apply them or click the back button to review a different search result. You should see your changes appear under the Details and Cover tab where you can perform further tweaks (manually edit fields, search for alternative covers or upload files from your hard drive).

6 MORE AUDIOBOOK EDITS

While editing your audiobook, explore the other tabs on offer: Files lists all the files that make up the audiobook, while the Chapters tab reveals if the book has any chapters (and timings) information attached to it.

» In many cases, these won't exist, so click Edit Chapters and scroll down to insert these timings yourself or click Lookup to perform an online search at Audible. If you've sourced MP3 files from Overdrive.com, then experiment with flicking the 'Use Overdrive Media Markers for chapters' switch to on under the main Settings dialog.

» If you discover the metadata provider you choose for your library isn't delivering the results you expected, you can change it by returning to the 'Settings → Library' screen and clicking the Edit button next to the library to access its settings. Once done, click Update Library, then click 'Force Re-Scan' to re-scan the entire library using that metadata provider.

» If you're navigating through your library reviewing and performing edits, save time by using the ← and → buttons to either side of the metadata properties window to move backward and forward through your library.

7 SET UP MULTIPLE USERS

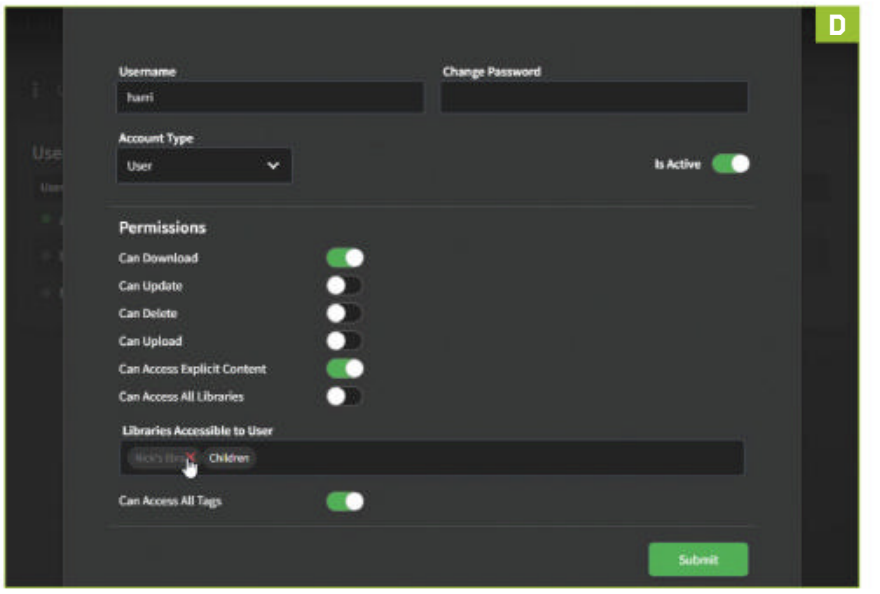
If you'd like to share some, or all, of your libraries with others, you can assign them their own user accounts, then limit their access to selected libraries only. Navigate to Settings, click ≡ and select Users from the slide-in menu. Click the + button to set up a username and password, account type (Guest, User, or Admin), and set permissions.

» These determine the level of access to Audiobookshelf—simple on/off switches include the ability to download, update, delete, and upload content, plus there's an 'access explicit content' for younger readers and the ability to limit access to selected libraries only (roll over a library in the list and click X to remove it) and by tag. You can also temporarily disable users using the 'Is Active' switch [**Image D**]. Click Submit when done.

8 ACCESS YOUR AUDIOBOOKS

You've set up your perfect audiobook and podcast library, but how do you browse your content and, crucially, access it? You can play audiobooks directly in the web interface—roll your mouse over a thumbnail and click the play icon. A player with controls will pop up at the bottom of the window giving you complete rein over playback. In addition to the obligatory play/pause buttons, you can skip forwards and back 10 seconds or jump between chapters, increase or decrease playback speed, set a sleep timer, and even bookmark specific sections of the audiobook for future reference.

» As you listen to more and more content, Audiobookshelf doesn't simply remember your place across multiple titles along with bookmarks, it also provides you with a stats panel (see sidebar, left) that provides such useful information as items finished, days when you've used Audiobookshelf, the number of minutes you've listened to, recent sessions (for easily jumping back in) and saved media progress.



9 ACCESS ON THE MOVE

You can also access your audiobook server via your smartphone. You'll find links to both Google Play and Apple Store at www.audiobookshelf.org. iOS users will need to install and set up Test Flight (see https://testflight.apple.com/ for details). The user interface is similar to the main web interface, so familiar and easy to navigate, albeit less fully featured.

» You can log in locally using the same IP you use to access the web interface (so http://192.168.x.y:8085/) or, if you set up the swag proxy server from October issue's docker tutorial, you can access it remotely. The reverse proxy configuration files are at https://github.com/linuxserver/reverse-proxy-confs. You may need to edit the 'set $upstream_app audiobookshelf;' line to 'set $upstream_app 192.168.x.y;' (the Audiobookshelf server's IP address). Log in using the subdomain address (https://subdomain.yourdomain.com) to access audiobooks from anywhere with an internet connection.

WHERE TO FIND AUDIOBOOKS

If you're wondering how to populate your server with audiobooks, you have plenty of choices. Audiobook CDs are usually split into dozens of tracks, many just one or two minutes long. That's good for listening to CDs, but not so convenient when building a digital audiobook library. The best ripping tool is iTunes, which lets you stitch multiple tracks together before ripping them—select your tracks, click the settings button and choose 'Join tracks'. Rename the first track in the grouped selection (eg. Chapter One or Disc One, Part One) before moving on to the next.

If you wish to transfer your Audible collection out of its DRM-locked ecosphere, OpenAudible (https://openaudible.org/) converts your books into MP3 format (with options to split the book into multiple files, one per chapter), allowing you to access them through Audiobookshelf.

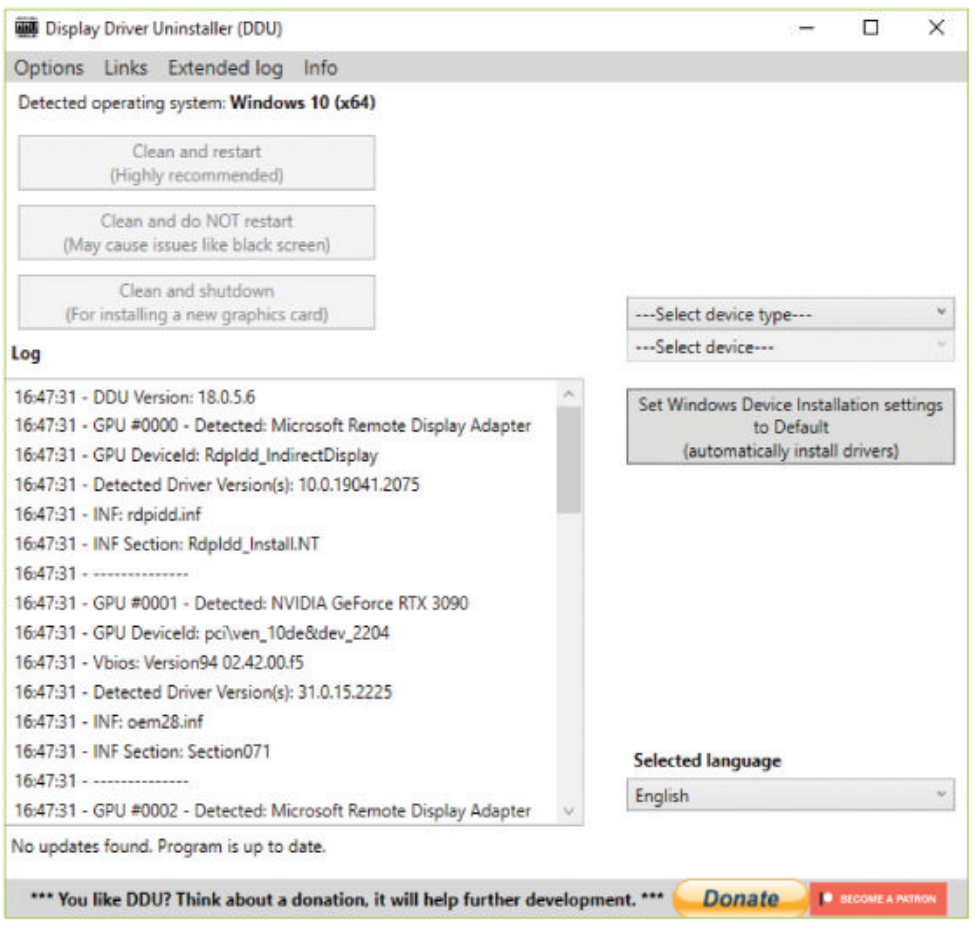
Finally, you'll find many free audiobooks for download online. These aren't restricted to just out-of-print books either but are public domain recordings of popular titles performed by volunteers. Start your search at LibriVox (https://librivox.org/), which celebrated its 17th anniversary recently with an announcement that over 17,000 audiobooks are now available to download.

How to Update Your GPU Drivers

YOU'LL NEED THIS

AN NVIDIA, AMD, OR INTEL GPU
Display Driver Uninstaller.

MOST PEOPLE TYPICALLY buy and install a new graphics card and leave it alone. Perhaps years may pass before it's again time for a GPU upgrade. In the interim, though, there will inevitably be plenty of driver updates made available. That's especially true when a new GPU architecture that comes along, such as Nvidia's Ada Lovelace, Intel's Arc Alchemist, or AMD's RDNA 3—the latter of which we'll take a deeper look at next issue. –JARRED WALTON



›› Display Driver Uninstaller doesn't bother with fancy logos or animations. It's simple, clean, and it gets the job done.

1 ALL GOING SWIMMINGLY?

You might think updating to new drivers is a relatively simple and painless process, and on the surface, it is. All three major GPU manufacturers provide the option to uninstall their respective drivers via the Control Panel. Furthermore, you can elect to do a 'clean install' when updating to the latest release. Most of the time, things will go swimmingly, with your PC and OS none the worse for wear.

›› But occasionally, things don't go so well. Sometimes you end up with corrupted drivers that won't uninstall properly, or they uninstall but leave behind undesired cruft. We've experienced situations where performance inexplicably drops, and the only way to ensure your drivers are working properly is to clean them.

›› It's also a good idea to execute a thorough cleaning of old GPU drivers if you happen to switch from an Nvidia GPU to an AMD GPU—or an Intel Arc GPU. For that matter, even if you just upgrade from an old Nvidia card to a new Nvidia card, wiping out any remnants of the older card is a good idea. Technically, you don't have to do this, but there's also no reason to keep the old drivers unless you're trying to concurrently run mixed GPUs on one system. [*Shudder!*]

2 TIME FOR A DEEP CLEAN

So how do you go about doing a deep cleaning of your graphics card drivers? The manual process would consist of scouring your drive and registry for any remnants. You'd probably miss some stuff, and there's certainly a chance you'd delete something you shouldn't.

›› Thankfully, a handy utility called Display Driver Uninstaller will do all the dirty work for you. It's been around a few years now and gets routinely updated. It also has support for removing audio drivers as well as graphics. The important thing is that it's programmed with all the knowledge of where AMD, Intel, and Nvidia store the various registry settings and files, so it knows exactly where to look at what to delete.

›› Perhaps the most difficult part of the process is getting DDU in the first place. The developer always has the latest version at www.wagnardsoft.com, but there are some advertising links and other buttons that can get in the way. Just look for the latest version (V18.0.5.6 at the time of writing), click that for a page that shows the changelog, then hit the 'Click here for download and support' link. Finally, on that page you should see a link that says '***Official Download Here***' and that will get you the necessary self-extracting Zip file.

›› Unpack that to whatever location you want, then open the 'Display Driver Uninstaller.exe' application. It will warn you about not being in Windows Safe Mode, a holdover from the pre-Windows 10 era. Don't worry about that; the program works fine without being in Safe Mode. (Reboot and run it a second time if you're concerned about it missing something).

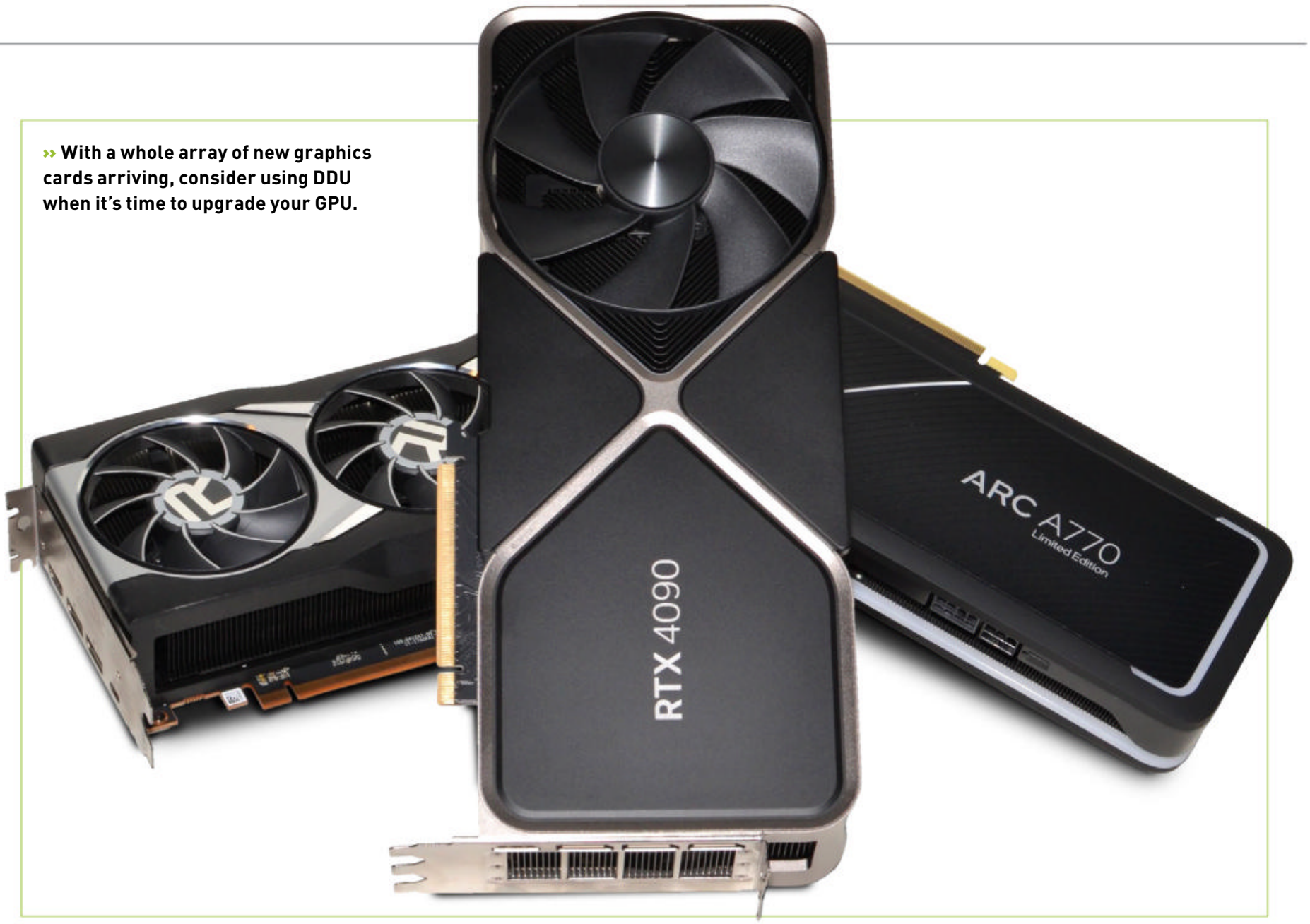
3 TAKE THE NUCLEAR OPTION

The settings are mostly self-explanatory, but it's worth taking a moment to configure the options. We don't want Windows automatically downloading new display drivers, so we check the appropriate box. We also turn off the automatic system restore point creation and the advertisements. Then we tell it to delete all the bits and pieces that come with modern graphics drivers.

›› Beyond that, all you need to do is select the appropriate device type—we only use it for GPUs, but you can try the audio option if you want—and then choose your GPU vendor. The app is smart enough to detect your currently active graphics driver and will default to that, but if this is the first time you've used DDU it won't hurt to wipe out any potential remnants from the other graphics vendors.

›› As an example, if we're using an Nvidia card, we start by selecting AMD and hitting the 'Clean and do NOT

© DISPLAY DRIVER UNINSTALLER



›› With a whole array of new graphics cards arriving, consider using DDU when it's time to upgrade your GPU.

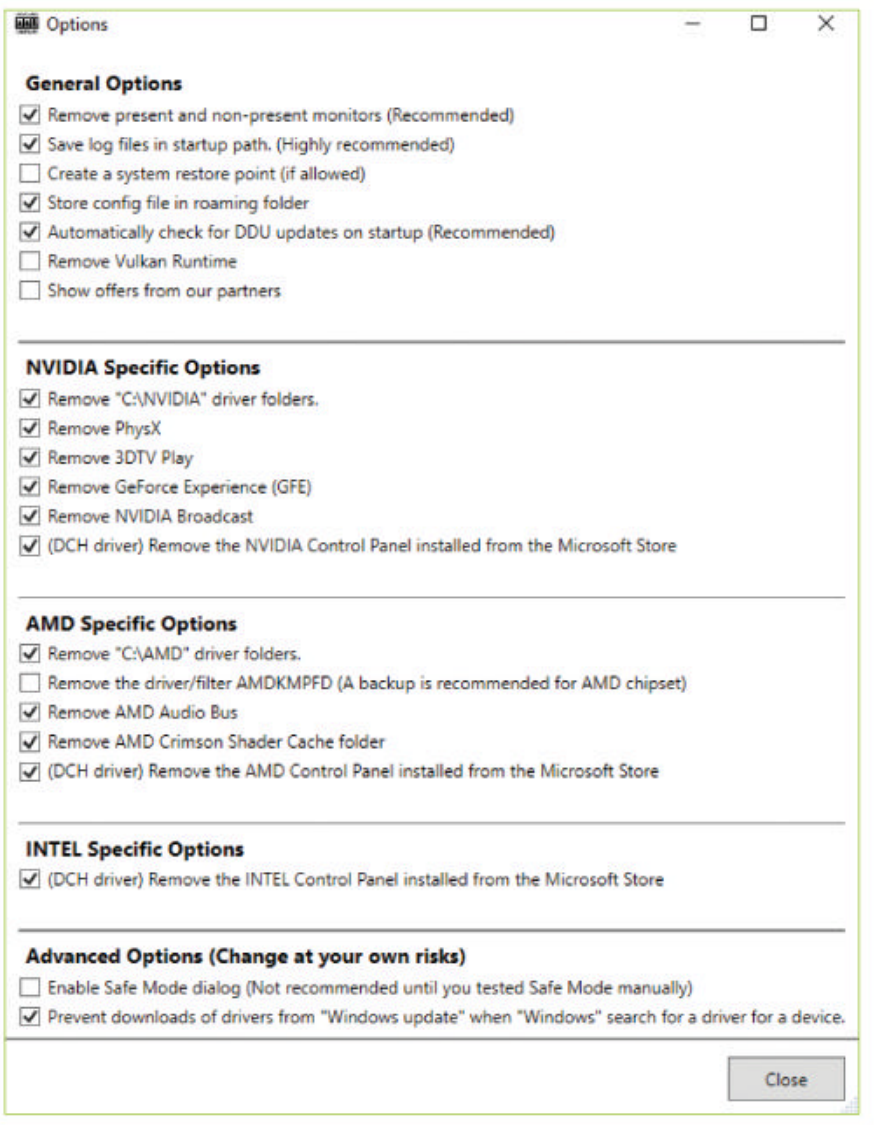
restart' button. After a minute or so, the program finishes the cleaning and asks if we want to exit. We choose 'No', then select Intel, again without restarting. Only after those are both gone do we move on to wiping out the currently active Nvidia drivers. This time, we choose 'Clean and restart'—or if planning on installing a new graphics card, opt for 'Clean and shutdown'. All three GPU vendors get nuked into oblivion. It's the only way to be sure.

4 PROBLEMS WIPED OUT

At this point, the PC should be good and ready to welcome whatever graphics card we might want to install for testing. You're probably not doing that, but following the same process still has benefits. We don't have a lot of hard data, but anecdotally, if you've never used DDU and have only relied on the GPU company uninstallers, there's a chance you'll see improved performance on whatever card you're currently using. Even if you don't, there's no harm in getting rid of old files you no longer need. We know someone who ran DDU and freed up over 20GB of drive space that was occupied by old driver installation files.

›› The bottom line is that our process for testing different graphics cards has benefited greatly from DDU. It only takes a few minutes to run, at which point, we can be reasonably certain any problems we might experience aren't due to driver cruft. For example, when AMD launched the RX 6700 XT, we had problems and informed AMD the card wasn't working properly. Their proposed solution was to wipe Windows and do a clean install. We were confident that wasn't necessary, but to give it a go, we used a different SSD on a clean Windows 10 installation. As expected, the problem was with the 6700 XT sample we received, and when they sent us a different card, it worked flawlessly.

›› These days, we don't swap GPUs without first wiping the old drivers using DDU. It's a must-have utility for any PC enthusiast, particularly when it's time for a graphics card upgrade.



›› Here are the options we use when running DDU. Kill it with fire' tends to be our motto!

LAB NOTES

JEREMY LAIRD, CONTRIBUTOR

Stop me if I'm repeating myself...

Intel's new Raptor Lake CPUs have a power guzzling problem

THIS SHOULDN'T COME as much of a surprise. Raptor Lake is, after all, a tweaked version of the Alder Lake just with more cores and higher clocks. And Alder Lake was already seriously pushing the wattage.

Intel can say all it wants about the 3rd-gen SuperFin process tech used to manufacture Raptor Lake, now branded as Intel 7. But the reality is that it's still a 10nm process in a world where the likes of TSMC have just started producing 3nm chips for commercial applications. Of course, process nodes aren't directly comparable between competing fabs. So, Intel's 10nm is actually a bit more dense than TSMC's 7nm technology. But however you slice it, Intel is miles behind.

Our benchmark results put Raptor Lake's CPU package power at around 250W in the case of the Core i9-13900K. But that's actually a best-case scenario. If you look at total platform power and use even more demanding software, it's possible to push the overall draw up to nearly 500W, at which point the delta to AMD's Ryzen 9 7950X is getting on for 150W.

Now, it's debatable how important power draw is on the desktop. An extra, say, 50W in any direction surely doesn't make much odds. But at some point, it becomes an issue and at least with high-end Raptor Lake models, we're surely approaching real-world problem territory. As I've mentioned in a previous issue, the recommended limit for a standard wall socket in the US is 1,440W. But anything over 1,000W is a bit worrisome, depending on the quality of your wiring and how many devices you have contending on a given loop.

In that context, just imagine adding Nvidia's new RTX 4090 GPU, which has been tested sucking up over 500W all on its own. If you ask me, this is all getting a bit silly. Quite literally, the power consumption of CPUs and GPUs can't keep going up like this. It just isn't sustainable in terms of plain old wall socket power, let alone any broader questions of sustainability.

Intel's Raptor Lake Chips are power-hungry beasts.

GUY COCKER

Editor-in-Chief

My cover build this issue with the RTX 4090 has made me realize the fact that we're finally in the era of the 4K graphics processor.

That means that through a combination of raw computing power and DLSS upscaling, you can be confident of playing nearly all games in 4K Ultra at 60 frames per second. True, some players are reporting that DLSS 3's generated frames have a detrimental impact on the 'feel' of the game, particularly in eSports titles. But the 4090, if you can afford it, is currently the king of the 4K gaming cards.

Luckily, I had access to the excellent Acer Predator XB323QK 4K 144Hz gaming monitor for testing, which allowed me to push the RTX 4090 to the max. But just for a laugh, I asked my AV journalist friend if I could bring the machine over to his house so that I could see what it was capable of on the Samsung QN900B Neo QLED 8K display.

To my surprise, games such as *Forza Horizon 5* and *Fortnite* were able to run at 60fps with *Cyberpunk 2077* and *Marvel's Spider-Man* running at 30fps in 8K. That makes the 4090 quite enticing for anyone with an 8K TV, as it's certainly something no current console can offer.

Sadly, there's not much available on the 8K monitor side of things right now, with only the Dell UltraSharp UP3218K ($5,000) currently up to the task at 8K 60Hz.

Editor's Pick: SteelSeries Arctis Nova Pro

To DAC or not to DAC? That is the question

IF YOU'RE anything like me, most of your free time is spent listening to music or at least having it on in the background. It's as if I can't function properly without it. An issue that this obsession has created is a need for decent sound quality. I've been lucky enough to test a range of audio equipment for this publication, including headphones, gaming headsets, and speakers. Testing everything up to audiophile-grade earphones costing $1,000 has left me in a space where I am spoiled for choice.

Listening at the highest possible audio quality opens up a whole new world of detail that is otherwise lost, either through your music source, audio peripherals, or incorrect settings. So every time I get a minute to relax to my favorite music, I make sure I'm not making any compromises. I'm currently using Tidal HiFi Plus as my source, which gives me one of, if not the best, audio streaming quality with an extensive library too. As for my weapons of choice, I've recently been testing the SteelSeries Nova Pro headset, which comes with a GameDAC Gen 2—and I have been more than impressed.

DACs (or Digital to Analog Converters) are a great way to ramp up your audio quality and fine-tune your listening experience, allowing you to pump out a richer and more powerful sound. They aren't always the easiest and most portable of solutions, often requiring their own power source via a mains plug. It means that, if you're using a DAC in a more permanent setup, such as a home office, then they are a great addition to your music system. If you're on the go and like to use a laptop to stream your music, then a USB-powered DAC like the one that comes with the SteelSeries is a portable option and an improvement over the auxiliary jack.

This little device can crank up your audio quality to 24-bit 96,000Hz, which is impressive, to say the least. It's also a quirky device with a fun setup process. On first boot-up, you're greeted with some prompts to read as you scroll through using the dial. The build quality here is spot on too. The dial itself is anodized metal that's cool to the touch and the font panel is entirely glass. It contains an OLED display and because it's hard to see the edges of the display, it creates a seamless look. The actual resolution is an 8-bit-esque style that suits the aesthetic and keeps things easy to follow. Around the back are two USB Type-C ports, so you can connect this up to two devices simultaneously. You'll also find line-in and line-out connectivity here. On the left side is where you connect using the 3.5mm auxiliary port.

Setup is as simple as plug-and-play. The dial works as the volume knob, but with a long press, you get into the menu, which includes USB input selection (to switch between sources), audio options (EQ, gain, MIC settings), line-out options, and then system settings (brightness, tutorial and reset). There's a touch-sensitive circle button on the front of the device which is the back button. Of course, you can access all of this within the SteelSeries GG application too, which I can recommend as it also gives it a firmware update.

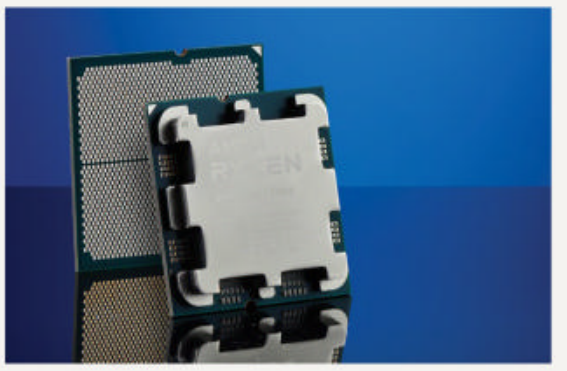
I'm impressed with this little device. I've tested the headset with and without the DAC and the difference is night and day. The Nova Pro headset is by no means a slouch, the DAC just gives it so much more texture and detail across all the ranges and a far deeper bass. **–SL**

$250, www.steelseries.com

Reviewed...

74 Intel Core i9-13900K

76 Intel Core i5-13600K



78 AMD Ryzen 7 7700X

80 Asus ROG Maximus Z790 Hero

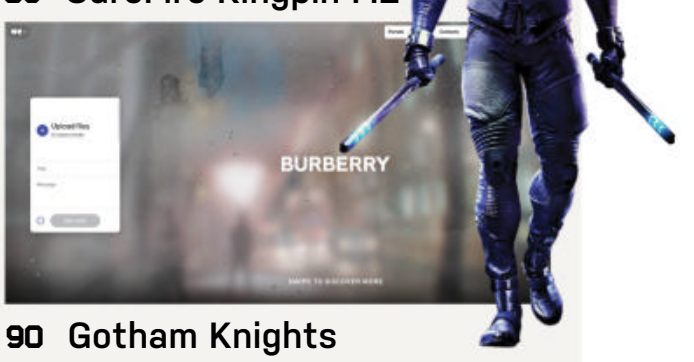
82 Intel Arc A750 Limited Edition

84 AOC Agon AG275QX

87 SteelSeries Arctis Nova 7 Wireless

88 Corsair Katar Elite Wireless

89 SureFire Kingpin M2



90 Gotham Knights

92 Google Drive vs. WeTransfer

Intel Core i9-13900K

Introducing Intel's new multi-core monster

THIS IS IT, then. Intel's reply to AMD's 5nm beast, the Ryzen 9 7950X. We give you the new Intel Core i9-13900K, all 24 cores of it. Yes, you read that right. For the new Raptor Lake 13th-generation family of CPUs, the most obvious upgrade is a doubling of efficiency cores from eight to 16. With eight high-performance cores retained, that takes the total core count to 24 and the threads to 32.

That makes for an uneasy comparison between AMD and its 16-core rival. Hold that thought while we consider the rest of the Raptor Lake upgrades. You get more L2 cache per core on those powerful P cores and more shared L2 cache across the low-power E-cores. As for the cores themselves, the P cores get minor tweaks to improve IPC or performance per clock, while the E cores are carried over. There are also optimizations to Raptor Lake's Compute Fabric, caching policy, memory subsystem, and ring frequency to support the beefed-up core counts.

The other major upgrade involves clock speed. The old Core i9-12900K Alder Lake chip topped out at 5.2GHz on its P cores. The new 13900K ups that to fully 5.8GHz. The E cores are faster, too, increasing from 3.9GHz to 4.3GHz. If you're a fan of high clock speeds, the upcoming 13900KS model will dump Intel's integrated graphics early next year and up the ante to fully 6GHz. Impressive.

One thing that hasn't changed is the 10nm process node used to manufacture Raptor Lake chips, otherwise known as Intel 7nm. Intel says it has been refined, calling it 3rd-gen Intel SuperFin for this outing. However, as we'll see when we ponder the power consumption of the 13900K, manufacturing tech remains Intel's greatest weakness.

But first, performance. And what a performance there is. Those E cores might be physically puny but they pack around two-thirds of the per-clock, single-thread performance of a P core. And there are now 16 of them. For pure multi-threaded throughput, the 13900K is as good as it gets. It's a massive 38 percent faster at video encoding versus the old 12900K, for instance, and 15 percent quicker than AMD's 7950X flagship CPU. It also comfortably outpoints the 7950X in terms of overall productivity in the PCMark 10 test suite. Not bad considering the AMD option is more expensive.

That's not to say the AMD CPU is trash. It has a slight edge in Blender 3D rendering. AMD's architecture still has plenty to offer. But the combination of high clock speeds and lots of cores makes the 13900K awfully compelling for getting serious work done.

As for gaming, the new Raptor Lake architecture isn't quite as dominant. To be clear, this is a stellar CPU for gaming. But it barely moves the needle compared with the old 12900K. In fact, it's actually a hair slower in some games, such as *F1 2021* and *Shadow of the Tomb Raider*. Arguably the bottleneck in such games isn't the CPU, but the 13900K still fails to dominate. Of course, the 13900K will give you every bit as good a gaming experience as any other top chip. But if it's mainly for gaming, the cheaper Core i5-13600K, also reviewed in this issue, will deliver the same experience for less cash.

So, the 13900K combines unbeatable productivity performance with highly competitive gaming grunt. On balance, that makes it the best CPU you can buy, right? There is one catch, namely power consumption. If the old 12900K was a gas guzzler, the 13900K is flirting with the dumpster. In our testing, the old 12900K hit 212W under the load and the 7950X 191W. The 13900K? Make that 252W.

How much that truly matters is debatable. But it does reveal the shortcomings of Intel's 10nm process node. And it implies a CPU running right at the ragged edge. As good as the 13900K undoubtedly is, Intel's upgrade to 7nm silicon can't come soon enough.

–JEREMY LAIRD

VERDICT **8**

Intel Core i9-13900K

+ GREAT POWER A multi-threading monster; super-high clock speeds.

– IRRESPONSIBILITY A serious gas guzzler; poor value for gamers.

$599, www.intel.com

BENCHMARKS

	AMD Ryxen 7 7950X	Intel Core i5-12900K	Intel Core i5-13900K
Blender 3.3.0 Junkshop (samples/min)	**175**	115	169
X264 5.0 video encoding (FPS)	94	79	**109**
PCMark 10 (points)	6,831	6,909	**7,310**
Far Cry 6 1080p (FPS)	152	171	**175**
Metro Exodus 1080p (FPS)	126	133	**134**
F1 2021 1080p (FPS)	176	**196**	192
Shadow of the Tomb Radier 1080p (FPS)	**216**	217	214
CPU peak package power (watts)	**191**	212	252
Max CPU temp (degrees C)	96	**87**	94

Best scores in bold. Intel test bed consists of an Asus ROG Strix Z690-F Gaming WiFi motherboard, 2TB Sabrent Rocket 4.0 Plus M.2 SSD, Asus ROG Ryujin II cooler, and Gigabyte Aorus P1200W PSU. AMD test bed features an ASRock X670E Taichi motherboard, 1TB WD Black SN850 M.2 SSD, Corsair H100i RGB cooler, and NZXT 850W PSU. Both systems used an Nvidia RTX 3080 10GB and G.Skill Trident Z5 Neo DDR5-6000 CL30 2x 16GB RAM.

SPECIFICATIONS

Socket	LGA1700
Production node	10nm (Intel 7)
Cores (P+E)	6+8
Threads	20
L3 Cache	36MB
L2 Cache	32MB
Max P-core Turbo frequency	5.8GHz
Max E-core Turbo frequency	4.3GHz
Graphics	UHD Graphics 770
Memory support (up to)	DDR5 5600MT/s, DDR4 3200MT/s
Processor base power	125W
Maximum Turbo power	253W

The new 13900K beast packs a total of 24 cores and 32 threads.

Intel's latest Core i5 'K' series chip is an all-round killer.

Intel Core i5-13600K

In this case, E's are most definitely good

SO, YOU'VE READ ALL about the mighty Intel Core i9-13900K. Realistically, that's a $600 CPU and not one that most of us are likely to be buying any time soon. However, the new Core i5-13600K is a different ballgame. This chip comes in at $330 and, without giving away too much too soon, it's stellar value.

As with its bigger Core i9 brother, the big news is the doubling of efficiency core count over its direct predecessor, in this case, the 12600K, and a jump from four to eight so-called E cores. When Intel first announced its hybrid architecture with the 12th-generation Alder Lake CPUs, not everyone was convinced. Some argued that they would rather have as many high-performance cores as possible, and the efficiency cores could go hang.

As it turns out, that hybrid approach works really well. A key factor is that four efficiency cores fit into the same die space as one performance core. But you get far more than a quarter of the performance of a P core. The result, as we'll come to shortly, is a remarkable combo of single and multi-thread grunt.

Anyway, the performance core count remains the same as the old 12600K, so you get six of the big P cores to go with those eight little E cores and, therefore, 14 cores overall. That's significant, because the AMD competition, respectively priced below and above the 13600K, comes in at six and eight cores in the Ryzen 5 6700X and Ryzen 7 7700X.

Core counts aside, the 13600K gets a few other upgrades over its 12th-generation progenitor. The boost clock jumps up from 4.9GHz to 5.4GHz and there's more cache memory across the board. The P cores step up from 1.25MB of L2 cache per core to 2MB, while the E cores have a shared 8MB of L2, up from just 2MB. Finally the shared L3 increases from 20MB to 24MB.

Most of the other details are pretty similar comparing this Raptor Lake-based chip with the previous Alder Lake model. You get the same 16 lanes of PCIe Gen 5 and four lanes of Gen 4 from the CPU socket, for instance. One notable exception is power consumption. More cores mean more power consumption, with the maximum Turbo power rating increasing from 150W to 181W.

But what does that all add up to in terms of performance? Straight out of the gate and the 13600K spanks the more expensive AMD Ryzen 7 7700X at most multi-threaded tasks. It's 15 percent faster at both 4K video encoding and 3D rendering, for instance. The gap is a bit tighter in PCMark 10. But when it comes to productivity performance, it's not much of a contest—Intel owns AMD.

Over on the gaming side of the equation, it's not quite such a no-brainer. The AMD 7700X actually just beats the 13600K in *Shadow of the Tomb Raider*. On the other hand, the 13600K has the edge in every other game we tested, and by a pretty wide margin in one or two. In terms of the subjective gaming experience, in reality, you'd probably struggle to pick the difference between the two CPUs. But that actually makes it another win for Intel when you take into account pricing. The 13600K is a chunk cheaper, after all.

Even better, the one area where Intel has struggled of late, power consumption, isn't actually too bad on the 13600K. OK, it is a bit more power-hungry than the 7700X. But only a few watts under heavy load. That's the benefit of Intel not clocking the twangers off the 13600K as they have with the 13900K. Those extra few hundred Hz on the bigger chip really hurt power consumption.

So, yeah, the new 13600K is quite a chip, probably our favorite of all the new-gen CPUs from Intel and AMD. With the doubled-up efficiency cores, it boasts a welcome injection of multi-threaded throughput to complement Intel's already excellent per-core grunt. We like. We like it a lot. **–JEREMY LAIRD**

VERDICT 9

Intel Core i5-13600K

HOT STUFF Killer all round performance; cheaper than the AMD competition.

HOT MESS You'll probably need a new motherboard; it could use a tiny bit less power.

$300, www.intel.com

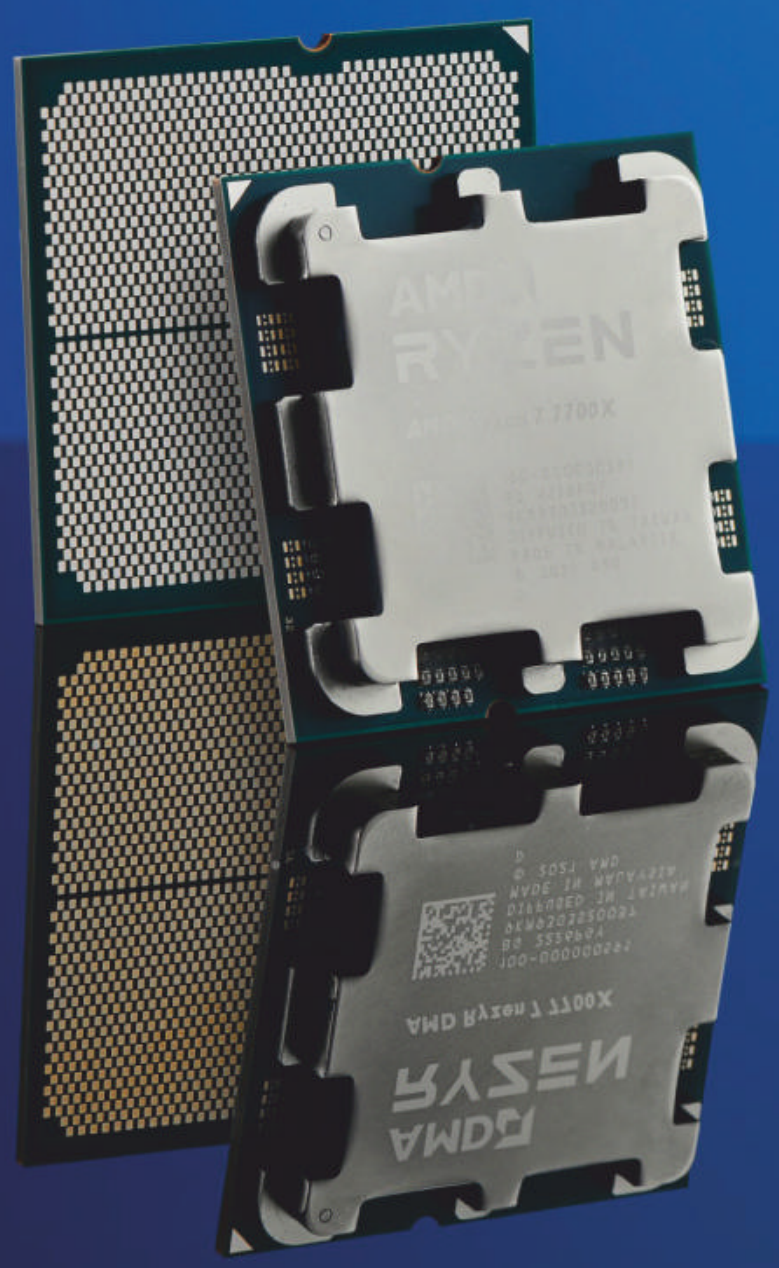
BENCHMARKS

	AMD Ryzen 7 7700X	Intel Core i5-12600K	Intel Core i5-13600K
Blender 3.3.0 Junkshop (samples/min)	64	53	**73**
X264 5.0 video encoding (FPS)	89	73	**102**
PCMark 10 (points)	7,005	6,742	**7,073**
Far Cry 6 1080p (FPS)	145	153	**171**
Metro Exodus 1080p (FPS)	128	131	**132**
F1 2021 1080p (FPS)	166	**195**	193
Shadow of the Tomb Radier 1080p (FPS)	205	211	**213**
CPU peak package power (watts)	143	**112**	147
Max CPU temp (degrees C)	96	**59**	72

Best scores in bold. Intel test bed consists of an Asus ROG Strix Z690-F Gaming WiFi motherboard, 2TB Sabrent Rocket 4.0 Plus M.2 SSD, Asus ROG Ryujin II cooler, and Gigabyte Aorus P1200W PSU. AMD test bed features an ASRock X670E Taichi motherboard, 1TB WD Black SN850 M.2 SSD, Corsair H100i RGB cooler, and NZXT 850W PSU. Both systems used an Nvidia RTX 3080 10GB and G.Skill Trident Z5 Neo DDR5-6000 CL30 2x 16GB RAM.

SPECIFICATIONS

Socket	LGA1700
Production node	10nm (Intel 7)
Cores (P+E)	6+8
Threads	20
L3 Cache	24MB
L2 Cache	20MB
Max P-core Turbo frequency	5.1GHz
Max E-core Turbo frequency	3.9GHz
Graphics	UHD Graphics 770
Memory support (up to)	DDR5 5600MT/s, DDR4 3200MT/s
Processor Base Power	125W
Maximum Turbo Power	181W



On paper, AMD's Ryzen 7 7700X seems ordinary, but it offers a generational leap in performance.

AMD Ryzen 7 7700X

This standard Zen 4 chip is no gap filler

AT FIRST GLANCE, the AMD Ryzen 7 7700X is the safest option of AMD's new Zen 4 lineup. It's an 8-core CPU with 16 threads, coming in at just under $400 and, specs-wise, nothing out of the ordinary. Compared with the other chips in the lineup, such as the Ryzen 9 7950X, which has the highest thread count of any chip out there and is cheaper and speedier than its predecessor, and the Ryzen 5 7600X, which is the highest-clocked mainstream CPU around at just under $299, the Ryzen 7 7700X begins to look like it may be a bit of a gap filler.

But a gap filler it most certainly isn't. Earlier in the year, AMD made a huge deal when it crammed a ludicrous amount of L3 cache into the Ryzen 7 5800X3D, making that chip the fastest AMD gaming CPU ever. However, fast forward to the present day, and (spoiler!) the Ryzen 7 7700X outperforms it in the majority of games. So there is certainly more to this chip than meets the eye.

Essentially, the Ryzen 7 7700X replaces the Ryzen 7 5800X in the AMD hierarchy. As mentioned above, this chip packs in eight all-new Zen 4 cores, and 16 threads, while offering an all-core frequency of 5.15GHz straight out of the box. That's some healthy stats right there—we even measured it running at 5.55GHz under single-core loads. This is last-gen overclocking performance from a stock Zen 4 chip. It contains the same 105W TDP as the Ryzen 7 5800X and 5800X3D, but its 5nm compute and 6nm I/O dies deliver efficiency improvements.

We were particularly impressed by AMD's Eco Mode (enabled via the Ryzen Master software), which is able to deliver 95 percent or above of the chip's stock performance, but at much lower power usage. Thermal figures and power consumption are lower, which also results in a quieter system overall. So, that's a win-win for everyone, right? When testing on Cinebench at 65W, we see results that are 95 percent of what we got when testing at 105W. That's pretty darn impressive and begs the question, why AMD didn't just make this a 65W chip in the first place?

EARNING ITS SPURS

As impressive as the efficiency mode is, it's the out-and-out gaming performance where this Ryzen 7 7700X is going to earn its spurs. To put it simply, it's one of the best AMD gaming CPUs out there right now. This processor keeps up with the Ryzen 9 7950X and wipes the floor with the old Ryzen 9 5950X when it comes to frame rates, mainly due to its impressive single-core 5.55GHz performance. These results showcase how amazing the 5nm CCD of the Zen 4 architecture is when compared to Zen 3. The performance per watt delta of this new chip offers over twice what the Ryzen 9 5950X does.

Of course, not all gaming performance lies in the CPU, you can easily be GPU bound, so it's important to take this into consideration. When building a PC, it's always better to spread your money around instead of blowing most of your budget on one component.

Thankfully, this new AMD chip isn't crazily expensive and it makes the top-end Ryzen 9 7950X more of a hard sell, considering its hefty $699 price tag. The only issue we have is almost inevitable with new tech. To accommodate these AMD CPUs, you will need an AM5 motherboard and DDR5 RAM. So, unlike switching from Intel's 12th generation to 13th generation chips, where they both use the LGA1700 socket and can be used on the same motherboard, the same cannot be said about AMD's new range.

Should this put you off though? Not really. This processor has a lot going for it and is far from a gap filler, as we said earlier. It's a great example of generational improvement, especially when it comes to the efficiency of the processor. You can easily run this in eco mode without experiencing performance loss, that's a great move forward for this new generation of CPUs.

The AMD Ryzen 7 7700X is an example of a reasonably priced processor offering futureproofing and a generational leap in performance. Chalk it up as another win for AMD. **–SAM LEWIS**

BENCHMARKS

	AMD Ryzen 7 7700X	AMD Ryzen 9 7950X	AMD Ryzen 9 5950X
Cinebench R23 Single-Core (Index)	**1,970**	1,934	1,617
Cinebench R23 Multi-Core (Index)	19,495	**37,112**	24,109
Blender 3.3.0 (Samples per minute)	89.3	**174**	124
Metro Exodus (DX12, Ultra, 1080p) (fps)	**128**	126	121
Shadow of the Tomb Raider (DX12, Highest, 1080p) (fps)	**220**	216	181
Far Cry 6 (DX12, High, 1080p) (fps)	145	**152**	136

Best scores in bold. AMD test bed consists of an ASRock X670E Taichi motherboard, Nvidia RTX 3080 10GB GPU, G.Skill Trident Z5 Neo DDR5-6000 CL30 2x 16GB RAM, 1TB WD Black SN850 SSD, Corsair H100i RGB cooler and NZXT 850W PSU.

VERDICT **8**

AMD Ryzen 7 7700X

ECO PRO Incredible eco performance; 5.15GHz performance under full all-core loads.

INTEL NO Struggles against Intel's Core i7-13700K.

$399, www.amd.com

SPECIFICATIONS

Cores	8
Threads	16
Socket	AMD AM5
CCD lithography	TSMC 5nm
CCD die size	70mm²
CCD transistor count	6.5 billion
IOD lithography	TSMC 6nm
IOD die size	122mm²
IOD transistor count	3.4 billion
Max boost clock	5.4GHz
Base clock	4.5GHz
L2 cache	8MB
L3 cache	32MB
Memory support	DDR5-5200 (non-OC)
TDP	105W

This is a great board for Intel Core i7 or i9 performance enthusiasts.

Asus ROG Maximus Z790 Hero

A premium motherboard for premium Intel builders

ASUS HAS built its Maximus range of motherboards to offer all of the features enthusiasts demand, such as the ability to safely overclock, plus no shortage of expansion slots and ports to expand as you go. In this regard, the ROG Maximus Z790 Hero has everything the most demanding of PC users will want in late 2022, including compatibility with the latest PCIe 5.0 and DDR5 hardware. Only the ROG Maximus Z790 Extreme betters it in Asus's Z790 range, with more I/O ports, a 10Gb LAN connection, and a better VRM setup for overclockers who want to push their hardware to the absolute limits.

Visually, this motherboard is pretty understated—it's a black ATX-sized board with a mirrored plate over the I/O shroud that lights up with the ROG logo. Though it's still clearly a gaming-focused board, it doesn't go overboard on the RGB. The mobo supports Intel's 12th and 13th-generation Alder Lake and Raptor Lake processors and has four DDR5 slots with support for up 128GB per stick, clocked up to 7800MT/s. It also has two PCIe 5.0 x16 slots, one PCIe 4.0 x16 slot, and five M.2 slots, although only one of the latter is PCIe 5.0 compatible.

If you plan on buying one of these faster drives when they become available, you'll need to install an included expansion card, which will take up one of the board's two PCIe 5.0 slots. Or you can run two GPUs in tandem using Nvidia SLI and AMD CrossFire, not that anyone does this anymore. Networking is impressive, with one 2.5G LAN port and a Wi-Fi 6E adaptor in the box, while there are ten USB-A ports, two Thunderbolt 4 ports, and one USB-C 3.2 Gen 2 connector on the back panel, which will be more than enough for even the most demanding of PC users.

TASTY TECH SPECS

If you're the sort of PC builder who enjoys having the latest and greatest tech, then you may have been salivating at those tech specs. This mobo is catered to PC builders looking to make the most of Intel's newest processors. We paired the board with the Intel Core i9-13900K processor, MSI GeForce RTX 4090 Gaming X Trio, and Corsair Vengeance 32 GB DDR5-5200 RAM (essentially the kit from this month's *Build It* feature on page 16). The only thing we couldn't do to max out the board's performance was use a PCIe 5.0 SSD, as there weren't any available at the time of reviewing.

Asus's BIOS is one of the easiest to navigate out of all mobo manufacturers, and users should update to the latest firmware. Head to the 'EzMode' and enable XMP settings on the RAM, and they will be good to go without the need for more tinkering. Those who want to push things further are well catered for in the BIOS's Advanced mode, where they can gently nudge the i9-13900K's 24 cores past stock values. Asus's teamed power stage design also allows the circuits to remain cool while providing power efficiently to the CPU, RAM, and other components. While most users won't need more performance from Intel's latest powerhouse chips (see reviews, pages 74 and 76), Asus's interface allows you to push its recent i7 and i9 releases safely and intuitively. For i3 and i5 chips though, this will probably be overkill.

If you don't need the latest tech, it's also worth looking at our comparison between this board and a much cheaper Asus Z790 DDR4 board in our *Build It* feature. Out of the box, there isn't much difference between performance in games using the cheaper DDR4 board and the more expensive DDR5 model. If you already own a Z690 board, it may be worth hanging on to it and putting your money towards the latest Intel chip and Nvidia/AMD graphics processor. For the serious gamer or creative type with a shiny new i9-13900K chip to house, this is the best motherboard you can get without spending silly money. **–GUY COCKER**

VERDICT **8**

Asus ROG Maximus Z790 Hero

HEROIC Loads of I/O; PCIe 5.0 storage; ready to safely overclock Intel's latest CPUs.

SHAMBOLIC Expensive; no 10Gb LAN port; PCIe 5.0 storage requires included expansion card.

$630, www.asus.com

BENCHMARKS

	ZERO-POINT	
Cinebench R23 Single (Index)	2,001	2,247 (12.3%)
Cinebench R23 Multi (Index)	27,016	35,457 (31.2%)
CrystalDisk QD32 Sequential Read (MB/s)	7,082	7,057 (-0.5%)
CrystalDisk QD32 Sequential Write (MB/s)	5,300	5,303 (0%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Z690 system consists of our Build It machine from the October 2022 issue (page 16), consisting of an NZXT N7 Z690 ATX mobo, Intel Core i9-12900K CPU, PNY XLR8 Gaming REV RGB 32GB (2 x 16GB) 3200MHz DDR4 RAM and PNY XLR8 XS3140 PCIe 4.0 NVMe 1TB SSD. The Asus ROG Maximus Z790 Hero build featured Intel Core i9-13900K CPU, Corsair Vengeance 32 GB DDR5-5200 RAM, and PNY XLR8 XS3140 PCIe 4.0 NVMe 1TB SSD. XMP was enabled on motherboard BIOS but no other overclocking performed.

SPECIFICATIONS

Size	ATX
CPU	Intel 12th & 13th Gen
Socket	LGA 1700
RAM	4x DDR5 (up to DDR5-7800+), 128GB limit
Chipset	Intel Z790
Expansion	2x PCIe 5.0 x16 (x16 or dual x8), PCIe 4.0 x16
Storage	6x SATA (6Gbps), 3x M.2 2242/2260/2280 (PCIe 4.0 x4, SATA), ROG Hyper M.2 expansion card (M.2 2242/2260/2280 (PCIe 5.0, SATA), ROG Hyper M.2 expansion card (M.2 2242/2260/2280 (PCIe 4.0, SATA)
Ports	BIOS FlashBack Button, Clear CMOS button, 2.5G LAN, Asus Wi-Fi, 2x Thunderbolt 4, 6x USB-A 3.2 Gen 2, 4x USB-A 3.2 Gen 1, USB-C 3.2 Gen 2, HDMI, Optical S/PDIF out, 5x Gold-plated audio jack
Audio	Realtek ALC4082
GPU feature support	Nvidia SLII, AMD Crossfire
Dimensions	305 x 244mm

Intel Arc A750 Limited Edition

A true mid-range competitor

LAST MONTH, we looked at the Intel Arc A770 Limited Edition (see Dec 2022 issue); this month we get to check out its little brother that wants so badly to play with the big boys but sometimes just ends up being annoying. Everything good and bad said about the A770 still applies, but this time, you only get 8GB of memory and there's no RGB lighting to brighten your day. The latter may not matter much to a lot of people, but the former can definitely put a dampener on performance.

Using the same suite of games and settings, this provides about 90 percent of the A770's overall performance, for 83 percent of the price. That's a win as far as pure value goes, at least if you're only looking at the cost of the graphics card. However, some games are starting to push beyond 8GB VRAM, such as *Forza Horizon 5,* where the A750 ends up about 20 percent slower than its big brother.

We have a full breakdown of the Intel Arc Alchemist architecture (see page 42), but the proof, as always, lies in the eating of the pudding. Or the rendering of the pixels. Against Nvidia and its RTX 3050 and even the RTX 3060, the A750 passes as a viable alternative. Meanwhile, it splits the difference between AMD's RX 6600 and RX 6600 XT, landing a little closer to the XT overall—in price as well as in performance.

Arc has other selling points as well, including solid video encoding/decoding hardware that currently takes on all contenders. The quality and performance of the QuickSync Video encoder tends to come out ahead of Nvidia, and AMD's video support by comparison lags far behind. Ada Lovelace might regain the lead—maybe—but at the time of writing, we're still waiting for additional applications to add hardware AV1 support for Nvidia. XeSS also holds promise as a DLSS alternative, and at least Intel isn't pretending that the only way to achieve good quality upscaling is via proprietary hardware and software.

ARC OF A DRIVER

If that were the end of the story, we could move on, but drivers continue to be the fly in the Arc ointment. There are plenty of games where Arc GPUs perform fine, but as a first true dedicated graphics card offering, it's understandable if lamentable that Intel still has issues it needs to work out. Drivers continue to improve and perhaps Arc cards will age like a fine wine. Alternatively, they might just turn into vinegar.

For example, if you were to look at the price and think the A750 might make for a reasonable upgrade to a slightly older PC, you'd be mistaken. The design and drivers apparently make PCIe Resizable BAR a 'requirement'—running on a platform that doesn't have ReBAR can reduce performance by about 25 percent on average. Intel's Tom Petersen even went so far as to say, "If you're looking for a graphics card that will work well in a system that doesn't support ReBAR, just go buy an RTX 3060."

That about sums things up with the first generation of Intel Arc graphics cards. If you want to try something truly different, when was the last time we had an even remotely viable alternative to the AMD and Nvidia GPUs? Not since the days of yore when S3 and 3dfx roamed the Earth. A few pretenders have tried to break into the market in the ensuing two decades or more, but none have managed to stick around.

However, Intel is one of the few companies that has both the resources and the expertise to give dedicated graphics a shot. And, unlike Apple, Imagination Technologies, or Arm, it also has a vested interest in the success of the PC ecosystem. The A750 won't win every battle, the adoption of technologies such as XeSS remains an uphill battle, and the wheels might occasionally come off. But it's an interesting option and we hope Intel sticks around for the promised future iterations. **–JARRED WALTON**

RAM BENCHMARKS

	Arc A750	RTX 3050	RX 6600	RTX 3060
9 Game Average	**76** / **57**	53 / 39	67 / 47	73 / 54
Borderlands 3	**87** / **62**	54 / 38	83 / 54	73 / 52
Control (DXR)	**81** / **55**	52 / 33	48 / 30	75 / 46
Cyberpunk 2077 (DXR)	**47** / 27	25 / 21	19 / 15	35 / **30**
Far Cry 6	97 / **74**	74 / 52	**100** / 67	97 / 71
Flight Simulator	66 / 47	50 / 35	54 / 36	**69** / **49**
Forza Horizon 5	65 / 60	55 / 45	**77** / 58	72 / **61**
Horizon Zero Dawn	85 / 74	72 / 55	97 / 70	**100** / **78**
Red Dead Redemption 2	**81** / **69**	50 / 41	63 / 50	69 / 56
Watch Dogs Legion	**70** / **51**	47 / 35	64 / 45	64 / 48

Best scores are in bold. All testing conducted with a Core i9-12900K, MSI Pro Z690-A WiFi DDR4, 2x16GB DDR4-3600 CL16, 2TB Crucial P5 Plus M.2 SSD, Cooler Master MWE 1250 Gold V2. Scores are average framerates at 1920x1080 / 2560x1440 ultra, or 1920x1080 medium / ultra with ray tracing enabled in Control and Cyberpunk.

VERDICT **7**

Intel Arc A750 Limited Edition

FINE WINE Impressive value; sound architecture; a good deal more choice...

VINEGAR Driver concerns; only 8GB VRAM; ReBAR required.

$289, www.intel.com

SPECIFICATIONS

Architecture	ACM-G10
Lithography	TSMC N6
Boost Clock	2050MHz
GPU Cores	3584
Memory	8GB GDDR6
TFLOPS FP32	14.7
Bandwidth	512GB/s
TBP	225W
Connectors	HDMI 2.0b, 3x DisplayPort 2.0 10G

The A750 Limited Edition omits RGB lighting, but more importantly, it cuts the memory down to 8GB, and that impacts performance.

AOC's latest gaming panel doesn't set any new standards, but it's a fantastic overall package.

AOC Agon AG275QX

Hitting the 1440p, 170Hz sweet spot...

© UNSPLASH

BACK IN THE good old days of 60Hz gaming monitors, 1440p panels were the sweet spot, thanks to a fine balance between visual detail and performance. That same trade-off still applies today. Arguably, 1440p remains the canny gamer's choice, it's just that refresh rates are now higher.

Enter the new AOC Agon AG275QX. As a box-ticking exercise, it pretty much nails all the key targets. It's a 27-inch 1440p model, offering a decent panel size and enough pixels for plenty of in-game detail, plus sufficient desktop real estate for getting boring stuff done in Windows.

To that basic proposition, it adds 170Hz refresh and 1ms response times courtesy of a quality IPS panel. You also get DisplayHDR 400 certification and the implied 400 nits of brightness, along with 94 percent coverage of the DCI-P3 digital cinema color space. That's not half bad. And it all costs around $350, making it a really appealing value proposition.

At this price, it's not a huge surprise to find that the AG275QX is a plasticky affair, but it has a fully adjustable stand that even supports rotation into portrait mode. There's good connectivity too, with dual DisplayPort sockets, two HDMI ports, and a USB-A. Sure, there's no USB-C, but that isn't hugely relevant in a gaming context as its power delivery won't provide enough juice to keep a gaming laptop charged.

Fire the Agon up and it's obvious there's plenty to like in practice and not just on paper. The colors pop and there's plenty of contrast on offer, far more than you'd expect given the pedestrian 1,000:1 official rating. With no local dimming this is not a true HDR display, but spool up something like *Cyberpunk 2077*, toggle the ray-tracing and HDR goodness and you won't be complaining. It looks pretty fabulous, especially when you consider the Agon's price point.

It's quick, too. AOC has included user-configurable pixel overdrive in the OSD menu. The fastest setting suffers from some obvious overshoot and is best avoided. But the medium setting is seriously fast while exhibiting barely a whiff of overshoot. Only OLED panels for triple the money offer a far superior response, the AG275QX is that good.

It's a similar story regarding latency. For the record, you can only access the full 170Hz via DisplayPort, the two HDMI sockets are limited to 144Hz, but for PC gamers, that's not an issue. For most, the returns in terms of latency and smoothness diminish dramatically above 170Hz. Certainly, we'd rather have this 1440p 170Hz panel than, say, a 1080p 360Hz monitor. And by a long way.

The AOC Agon AG275QX is a strong overall package, but if we were being critical, the factory calibration could be improved. The colors are a little oversaturated by default and you'd want to manually calibrate the panel before doing anything even remotely resembling serious content creation. As it happens, the panel's calibration for SDR content is better when running in HDR mode, which makes for an easy quick fix. It also means you can run this panel in HDR mode all the time, rather than jumping back and forth between SDR and HDR depending on the content you're playing or watching.

It would be unfair to penalize the AG275QX too harshly for its suboptimal content creation calibration. That's well outside this monitor's remit. As a tool predominantly for gaming with a little general-purpose computing on the side, it's very nice indeed. **–JEREMY LAIRD**

VERDICT **8**

AOC Agon AG275QX

+ HOW REFRESHING Quick, high-quality IPS panel; strong package for the price.

– THIRSTY WORK Not a true HDR panel; default calibration could be improved.

$350 (estimated), www.aoc.com

SPECIFICATIONS

Screen size	27-inch
Panel type	IPS
Resolution	2,560 x 1,440
Brightness	400 nits
Contrast	1,000:1
Response time	1ms
Refresh rate	170Hz
Color coverage	94% DCI-P3
HDR support	DisplayHDR 400
Adaptive sync	FreeSync Premium, G-Sync Compatible
Connectivity	DisplayPort 1.4, 2x HDMI 2.0, USB-A hub

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SteelSeries Arctis Nova 7 Wireless

Is it a step forward or a step backward for SteelSeries?

AMONG THE three-strong Nova lineup from SteelSeries, the Nova 7 sits right in the middle. The three different variants include the Nova 7, the PC-optimized version we have on test here, the Nova 7P optimized for PlayStation, and the Nova 7X—yep, you guessed it—optimized for Xbox consoles. Costing just short of $180, it's not exactly at the budget end of the headset market, so is this new addition worth an upgrade or are you better off grabbing an older SteelSeries headset that offers better value for money?

Unboxing the Nova 7, you not only find the headphones but a range of cables and adapters too. There's a multi-platform USB-C wireless dongle, a 5ft USB-C to USB-A charging cable, a 5ft USB-C (female) to USB-A extension cable, and a 3.5mm auxiliary cable. The headset is also wireless via Bluetooth, offering a healthy amount of connectivity choices.

We aren't huge fans of the Arctis Nova 7's design though, especially compared with some of the company's older models such as the Arctis 9 wireless. There's nothing wrong with the design, it looks modern and slick in the matte-black finish of our review sample, but it's not as alluring as previous models.

Unfortunately, it falls short when it comes to build quality. The plastic feels cheap and scratchy and not what you'd expect from a headset costing $180. The elasticated suspended headband design has been swapped for a band that clips into place. It's still comfortable but doesn't offer as precise adjustment as before. The retractable built-in microphone sits flush with the earcups and the foam padding on the cups is plush. You can also customize your headset with different bands and earcup plate designs from SteelSeries.

On the left, there are controls for the mute function, volume control wheel, retractable mic, and the 3.5mm port. On the right is a volume wheel for game/party chat, the power button, the Bluetooth button, and the USB-C port. As we mentioned earlier, the materials used feel cheap and that's especially noticeable on the contact points, but overall, the Nova 7 headset feels sturdy and is comfortable too.

What really matters is the performance and, on this headset, gaming audio quality is top-tier—something that we have come to associate with SteelSeries for a while. One thing we should point out is that it's worth installing the native software, in this case, the SteelSeries GG application. This included a firmware update for the headset, which we installed before testing. In the app, we selected the bass boost EQ and this gave us the best sound. Where the standard preset lacked a little oomph, the bass boost EQ fixed that.

With the software sorted, the Arctis Nova 7 wireless offers a well-rounded and detailed soundscape. Playing games such as *Assassin's Creed: Origins* and other open-world titles, the Nova aids immersion without sounding muddy. Directional accuracy in competitive FPS game modes was also pinpoint, another strong point of SteelSeries headsets. The same goes for the microphone, pickup was strong and, on recordings, our voice sounded bright and clear.

There isn't much we can say negatively about the sound. If anything, it could offer deeper bass as standard but that can be addressed in the app. Where the headset doesn't live up to the price tag is in the overall design and build quality. For around the same price, you can pick up either the Arctis 7+ or the Arctis 9+, both of which offer similar audio profiles and much better build quality. – SAM LEWIS

VERDICT 7

Steelseries Arctis Nova 7 Wireless Headset

TOP GEAR Clear gaming-focused audio; 38-hour battery; great connectivity; comfortable.

REVERSE A step back in physical quality; better-priced alternatives available.

$180, www.steelseries.com

SPECIFICATIONS

Driver type	40mm Neodymium driver
Frequency response	20Hz-22kHz
Impedance	36 ohms
Connectivity	2.4GHz low latency wireless, Bluetooth 5.0, USB C, and 3.5mm auxiliary.
Compatibility	PC, Mac, PlayStation 4, PS5, Nintendo Switch, Mobile
Battery life	38 hours
Design style	Closed back

Corsair Katar Elite Wireless

Does this Katar provide razor sharp accuracy or is it a blunt instrument?

YOUR MOUSE is the bridge between your impeccable gaming mindset and proving your ability. A good tradesman never blames his tools, but it does always help to have good ones, of course. Corsair certainly offers a range of good tools, whether that's keyboards, headsets, or mice. This Elite variant is the latest and most premium offering in the Katar mouse lineup. The design doesn't stray far from the range's format, so is this new entrant the best Katar mouse of all?

In the box, there's a USB Type-C to USB Type-A cable and a wireless USB dongle hidden in a small compartment beneath the mouse. These pesky receivers can easily get lost, so we always prefer it when the mouse can house the dongle. The Katar Elite follows a similar design to the most recent Katar siblings, the Katar Pro XT and the Katar Pro. The design favors the claw and fingertip gripping techniques and is symmetrical. It's coated in a soft matte finish, which feels comfortable in the hand but can start to look greasy after a little use.

We prefer this smoother choice of material in comparison to the Katar Pro Wireless with its more textured surface. Speaking of which, on either side of the mouse, there's a textured plastic grip where your thumb and little finger sit. This might be more effective if it was rubberized, but it does a good job of helping you keep control when quickly flicking the mouse.

Another feature that helps maintain full control is the PTFE feet and sensor surround. Paired with the super lightweight design, this helps it to glide effortlessly. There's virtually no drag when swiping this device around your mouse mat, which makes using the Katar Elite a breeze. Unfortunately, build quality takes a slight knock due to its lightweight nature. Although the buttons feel nice and responsive, the mouse is so light it almost feels hollow. It's a lightweight gaming mouse, so it does get a pass for this but it's worth noting that it may feel a little cheap when you're using it for day-to-day tasks.

The two primary buttons feature Omron switches and Corsair Quickstrike button technology. This means there are zero gaps between the key and the switch, resulting in low travel and almost instantaneous actuation. This combination makes it an ideal gaming mouse, giving you a seamless response time. The scroll wheel is decent but too light for our liking. The feedback when hitting the increments is soft, meaning that you can unintentionally scroll further than you'd like. Thankfully, it's rubberized and has plenty of grip. There are also two side buttons where your thumb sits, set to go forwards and backward in a browser as standard.

CUSTOMIZABLE OPTIONS

But this, along with many other of the mouse's settings including polling rate, DPI, and RGB options can be changed within Corsair's iCUE software. If you don't want to dive into the software, there's a dedicated button below the scroll wheel to change it on the fly, featuring color-coded DPI increments.

On paper, the Katar Elite's specs improve on those of its predecessor with a higher DPI sensitivity of 26,000. Admittedly, that's impressively fast but the option to change it is there. It also contains a Marksman 26K sensor that, during our testing, performs responsively and accurately. These factors ensure this mouse is aimed towards speed-dependent gamers, such as those who play competitive FPS titles. As it doesn't feature an abundance of macro switches, we wouldn't necessarily recommend this lightweight mouse for MMORPG players, for example.

Anyway, it's fair to say that this mouse ticks a lot of boxes for competitive gamers. It has a pin-point accurate sensor, rapid DPI, and polling rate options available within the iCUE software. It's lightweight, has a silky smooth gliding action, and a rechargeable battery with a long life. It also offers three types of connectivity, either through Bluetooth, USB Type-C to Type-A cable, or via the Slipstream USB dongle—we'd recommend the latter for the most seamless experience.

If all that sounds pretty good, that's because it is, but a few things let it down. The mouse could benefit from rubberized grips and a stronger scroll wheel, and it also feels cheap due to its lightweight nature. If you can look past these issues, the Corsair Katar Elite Wireless is a dependable gaming mouse. –SAM LEWIS

VERDICT **8**

Corsair Katar Elite Wireless Mouse

SHARP Feather-like weight; 110+ hours battery life; pinpoint accuracy.

BLUNT Plastic grips; hollow feel; soft scroll wheel.

$80, www.corsair.com

SPECIFICATIONS

Sensor	MARKSMAN 26K
Max sensitivity	26,000 DPI
Polling rate	2,000Hz (adjustable)
Mouse switches	Omron mechanical
Connectivity	Slipstream wireless, Bluetooth, USB Type-A to USB Type-C
Weight	0.15lbs

SureFire Kingpin M2

A dependable mechanical keyboard for $50?

WHEN IT COMES DOWN to computing, the keyboard is (in most cases, literally) your right-hand man. Your typing instrument of choice needs to be reliable, comfortable, aesthetically pleasing, and a strong performer. Not every keyboard is going to tick all of these boxes, especially when it comes to the budget end of the market, but the SureFire Kingpin M2 looks promising. So, how many boxes does this full-sized mechanical model tick?

The first thing we picked up on when testing was the weight. Weighing in at 2.25lbs, it feels sturdy and well put together. Unless you want a portable wireless keyboard, this extra weightiness is an added benefit as it keeps the board from sliding around on your desk. That's handy because the rubber feet on this keyboard are pretty small. Next to the feet, there are two small kickstands with only one level of adjustment. It's a reasonably comfortable angle but would benefit from a wrist rest for a less strenuous experience.

For the price, the overall build quality is impressive. A metal front panel for under $50? Count us in! There are none of the nasty, sharp plastic edges that you often find in the budget keyboard market. The design isn't anything revolutionary, but that's a good thing. SureFire hasn't opted for a futuristic 'gamer-focused' design and has instead kept things basic with some RGB through the keys and slim RGB bars on each side of the keyboard. With an even glow, it's pretty impressive.

There are six function key buttons to change the RGB directly on the board, which seems like overkill. Talking of functionality, this is a full-sized keyboard that comes with a numpad and a top row of function and media keys, though you won't find any dedicated volume knobs or macro switches here.

We mentioned that the overall build quality was initially impressive, but things take a turn for the worse when we try out the keys. These caps are slippy and under more intensive gameplay, this could be an issue. The last thing you want to do when playing *Modern Warfare 2* is go for a sprint but your finger slips down to the CTRL key and you're caught crouching in open play. Okay, we're making it sound as though the keyboard is covered in oil, but you get the point.

PRESSING ISSUES

Performance-wise, the Kingpin M2 contains linear red mechanical switches. It boasts 100 percent anti-ghosting and a 1ms response time. Anti-ghosting is great to see here as it means regardless of how many key presses you actuate at once, none of these signals will be lost—again, that's pretty good for a keyboard with this price tag. Sure, there are no official Cherry MX switches here but these keys have a quick actuation with consistency across all the keys.

If anything, we'd like a little more haptic feedback as the keys are pretty light, however, they have all the speediness you need for gaming. So physical performance on the whole is good, if not great, but how does this perform audibly? The sound of a keyboard is a subjective issue—some like their board to sound dampened and deep whereas others prefer a lighter clicky sound. The Kingpin M2 fits more towards the latter preference, but unfortunately has a cheapness to it. Though it's clicky, it's not quite in the way you'd hope for—it's more the result of cheap plastic keycaps.

Although the cable used here is braided, longevity could be an issue. Trapping or bending a cable is something we can all admit to doing and, if it breaks, it will practically void the whole keyboard.

So what do we have here then? SureFire has produced a well-balanced budget keyboard with this Kingpin M2. It offers mechanical linear performance, speedy actuation, a strong construction on the whole, and a smattering of RGB lighting. Of course, it's missing features such as dedicated media and macro keys, a detachable USB cable, passthrough USB accessibility, and a wrist rest, but for all those extras, you'd be looking at a keyboard costing $100 or more. The Kingpin M2 is still a good choice for a budget keyboard, especially if you're into gaming. –SAM LEWIS

VERDICT 7

SureFire Kingpin M2 Keyboard

SURE 100 percent anti-ghosting keys; strong build quality; fast actuation.

UNSURE Non-detachable cable; small kickstand; cheap sounding key-presses.

$50, www.surefire-gaming.com

SPECIFICATIONS

Switches	Red Mechanical Switches
Switch Durability	50 million presses
Design Style	Full size RGB mechanical
Connection	Braided 1.8M USB Type-A
Wrist-rest	None
Weight	2.25lbs

In the big man's absence, Robin is at the helm of this ARPG.

ACTION ROLE-PLAYING GAME

Gotham Knights

The latest Batman(ish) game keeps it in the family

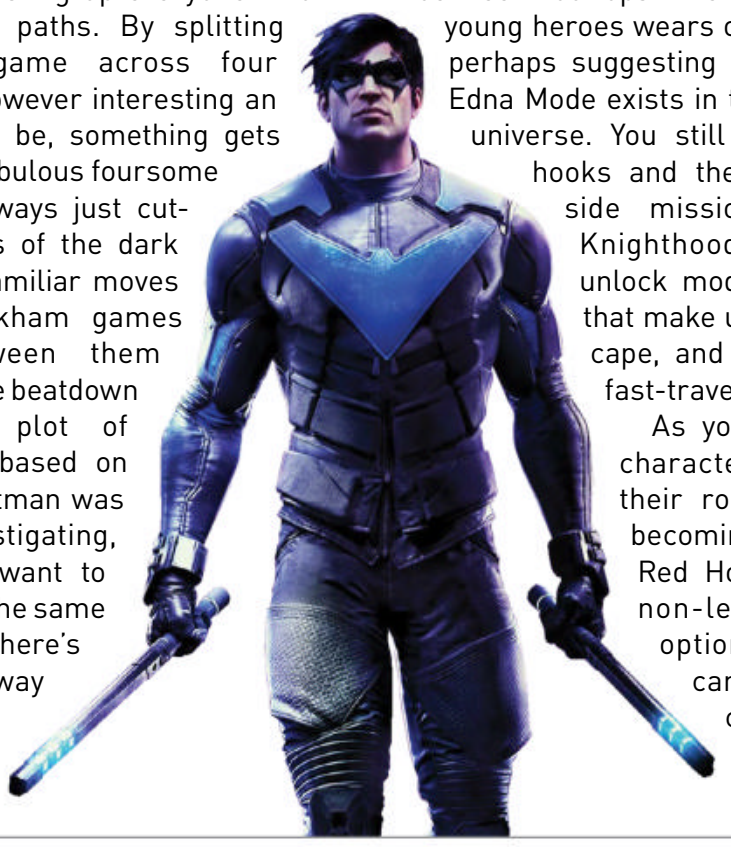
A BATMAN GAME without Batman is a bit of a hard sell. Perennial sidekick Robin may be strong enough to lead the Teen Titans, but can he helm an ARPG? Robin (the Tim Drake version) is joined by Nightwing, Red Hood, and Batgirl (Barbara Gordon), and can be played in online co-op. Batman may be absent, but there's no shortage of vigilantes to take his place.

While *Gotham Knights* might look and sound like it comes from *Batman: Arkham Asylum* developer Rocksteady Studios, it's not that either. This game was made by WB Games Montreal, the developer behind *Batman: Arkham Origins*.

Jim Gordon's dead too, though exactly how terminal death can really be when you're a famous comic-book hero is a matter open to question. This leaves Gotham City open to a criminal takeover from the usual ludicrously named suspects, this time including the Court of Owls, a secret society of wealthy sociopaths intent on taking over the city with undead soldiers, which is as much urban myth as world-controlling supervillain conglomerate until proven by our heroes to be very real indeed. The League of Shadows is involved too, along with The Penguin, Mr. Freeze, multiple Man-Bats, and more familiar faces.

There's a lot going on and a change in priorities has turned the game from an action-adventure to an action-focused RPG, with an emphasis on leveling up and improving stats. Here, the young heroes make more sense than Batman being weakened at the beginning of the game.

In the big man's absence, the four junior crusaders attempt to take back the streets of Gotham in time-honored fashion—by beating up everyone who crosses their paths. By splitting a Batman game across four characters, however interesting an idea that may be, something gets diluted. The fabulous foursome are in many ways just cut-down versions of the dark knight, with familiar moves from the Arkham games divided between them (Batgirl has the beatdown move). The plot of the game is based on something Batman was already investigating, and they all want to fight crime in the same way he did. There's no getting away from the Bat.



In the beginning, before you've had a chance to start unlocking their skill trees, all that differentiates the characters is their size and color (though Nightwing looks so much like Trent Reznor that you expect industrial metal to break out any second). One of the best things about the Arkham games, which date back to 2009, was Batman's cape snapping out behind him as he went for a glide between rooftops—the fact none of our young heroes wears one is a travesty, perhaps suggesting The Incredibles' Edna Mode exists in the DC extended universe. You still have grappling hooks and the Batcycle, plus side missions known as Knighthood Quests to unlock modes of transport that make up for the lack of cape, and you can unlock fast-travel points.

As you progress, the characters grow into their roles, with Robin becoming stealthy and Red Hood a tank with non-lethal ranged options, and you can return to the central Belfry

Hitting criminals until they're sorry—Batman's legacy lives on.

Fights take so long, you start wishing you were Batman.

A bizarre dancing game involving Red Hood and lots of green mist.

Find the culprit who's been stealing from the fridge.

location (a second Batcave Batman didn't tell anyone about) to swap characters if you find yourself in the wrong body. Once there, you can change costumes (a huge range is available for each character and the Batcycle, with outfits based on comic-book appearances) and weapons, as well as craft stat-improving accessories and play Spy Hunter on an arcade cabinet.

You also get to read our heroes' emails, which try to broaden their characters by portraying them as a bunch of roommates. Someone's stealing from the fridge, Nightwing likes annoying Batgirl, Robin wants to set up a podcast, and Red Hood plays a dancing game with green mist spraying from his hands. It's meant to be a manifestation of his trauma from a backstory that involves being brought back to life but comes across as bizarre.

Despite the four characters' emerging differences and the fact they level up together no matter which one you use, it's possible to progress through the game with the character you like the most. Nightwing makes a good all-rounder and co-op team-ups make the most sense during the supervillain boss fights where, despite the overlap, their abilities interlock in the classic interplay between healer and damage sponge, whoever is being attacked concentrating on dodges while the other player brings the hurt.

Otherwise, there's a lot of punching goons in the face, and the game brings in the undead to provide a source of infinite fist-fodder with little individuality. You pick your character and head out on patrol in the rainy darkness, continuing Batman's legacy of hitting individual criminals until they're sorry rather than actually doing something about the systemic issues that forced them into crime in the first place.

While you're dealing with street gangs, something will happen and you'll be sucked into a story mission, but side quests continue to suggest themselves. Batman's Detective Mode makes a sort-of return in the form of AR, which helps mark targets but is mainly used to solve puzzles. Once you've mastered the controls and advanced a few levels, you get the hang of balancing crowd control with charging the Momentum meter that allows special moves. But then enemies with specific takedown routines show up to ruin your flow, boss fights are much too long as a solo player, and you start wishing you got to play as Batman.

Performance-wise, there is some controversy about the 30fps lock imposed on owners of the latest consoles, which should be able to do better. There are no such limitations on the PC, but some players report stuttering that hasn't been fixed by the reinstatement of the Denuvo DRM software. Hopefully, another patch will be incoming by the time you read this—the first one, a few days after the game's launch, addressed UI and crashing issues but didn't alter the framerate.

Gotham Knights is a charming but unexceptional entry into Batman's videogame canon. While it's nice to see the foggy city updated for the newer generation of graphics hardware, the game's combat lacks the finesse of the earlier games, and *Gotham Knights* is far from the spiritual successor to Arkham City it would appear to be. **–IAN EVENDEN**

VERDICT **7**

Gotham Knights

BATMAN Story-rich, co-op focused update to the Batman Arkham games.

MANBAT Lacks the focus and tight combat of the original games.

RECOMMENDED SPECS CPU, i7-10700K/Ryzen 5 5600X. RAM, 16GB. GPU, GeForce RTX 2070/Radeon RX 5700 XT.

$60, www.gothamknightsgame.com, T-rated

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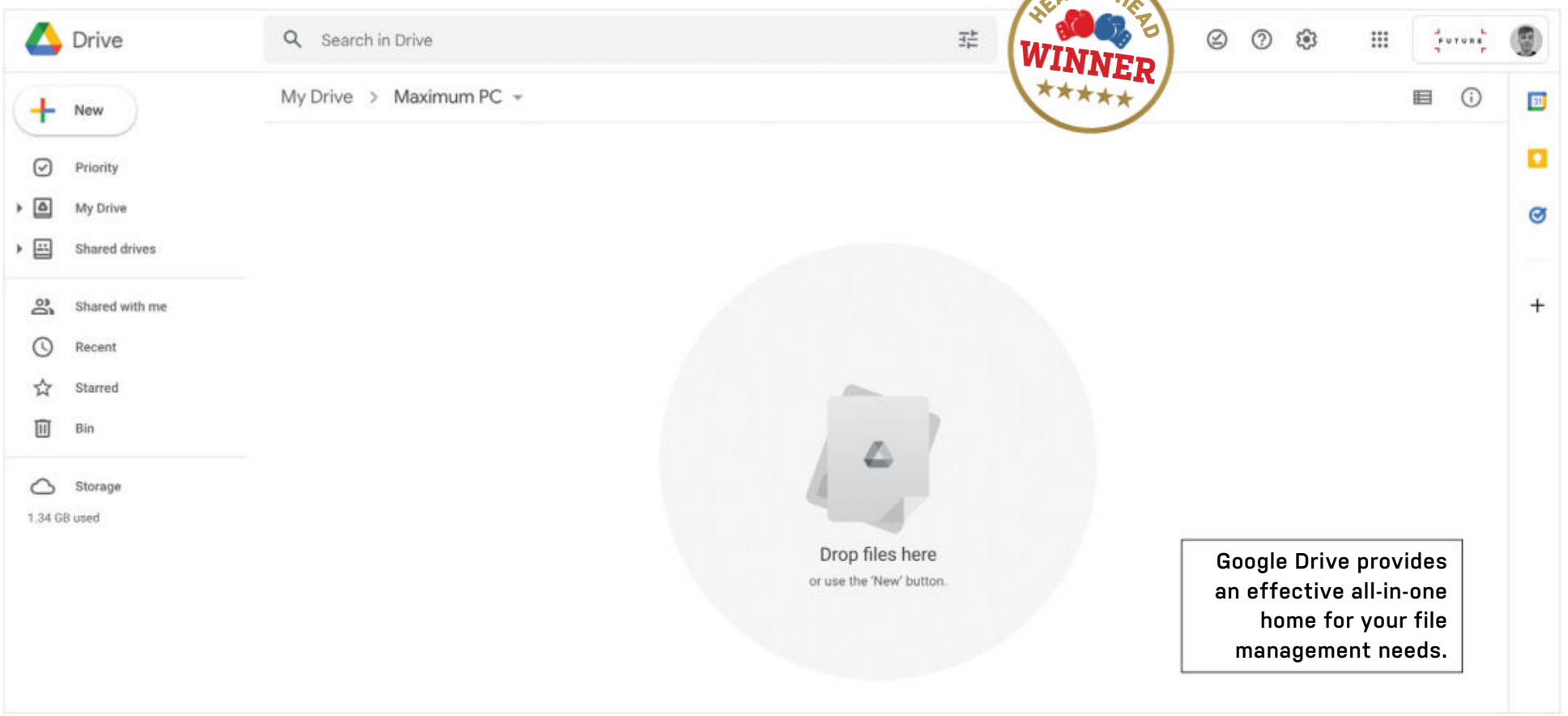

Google Drive provides an effective all-in-one home for your file management needs.

Google Drive vs. WeTransfer

Which side are you on for file sharing?

GONE ARE THE DAYS of sending a USB stick containing work, photographs, or other important documents over to your colleagues via snail mail or carrier pigeon. If you are clinging on to the old ways, then fair enough, but times have changed and there are now much quicker and more efficient ways of sharing your files across the internet.

Thankfully, using the cloud is a much more effective and secure method of sharing data. There are plenty of cloud services out there, but two of our favorite methods are Google Drive and WeTransfer—the two titans of the data-sharing world. Although both platforms differ in many ways, at their core, they both allow you to send and receive files for free. Paid options are also available for both services and we will touch on the finer details of these later.

Both of these services are fairly recent inventions. WeTransfer was founded in 2009 by Bas Beerens and Ronald "Nalden" Hans in Amsterdam, Netherlands. The pair simply wanted to solve a problem they were experiencing at the time, which was sending large intensive design files across the internet. At its launch, WeTransfer had humble beginnings—its only function was to send files of up to 2GB in size for free.

But just three months after it launched, WeTransfer was being used in 187 countries around the world, so it's fair to say that lots of other people had also been experiencing the same problem. Since then, the WeTransfer platform has expanded into a multitude of services, including WePresent, Paper, Teams, Portals, Collect, and Paste.

Google Drive was created in 2012 and has a slightly different identification as a file storage and cloud platform. Offering a lot more features than WeTransfer, it aimed to be the all-in-one platform for sending, receiving, and managing files, either for personal or business use. Of course, being a Google product, it integrates nicely with the rest of the Google Suite, creating an almost seamless ecosystem.

That said, if you are already a part of this suite, is WeTransfer a better bet for efficient file sharing, or is it worth sticking with Google Drive? These two services have similar core abilities but there are a few key differences. There is more than meets the eye with these applications so we're going to put the free offerings head-to-head to see which is more worthy of your precious uploading time.

On paper, you might be happy with the features that a service offers and the way they've been laid out. However, if you then use that service and it's a clunky, unorganized mess of an application, chances are you aren't going to want to use it. That's presumably what the team at WeTransfer had in mind when they designed its UI. Based upon founder Bas Beeren's creative studios, OY Communications, from the start, WeTransfer featured a clean interface and seamless navigation, creating a smooth experience for the users. Those characteristics are still prevalent today, and we found the WeTransfer site to be well-designed and easy to use.

The main part of the landing page includes a box where you can upload your files and send them. There are further links and information in a bar along the top right corner of the page and other tools in a drop-down icon from the top left. The majority of the page includes an advert that is often live or interactive and is seamlessly designed with WeTransfer in mind. Although not everyone wants to look at an advert, it is located in a place where it's not too intrusive and we don't mind it being there given the free service.

AD-FREE SERVICE

However, when using Google Drive, we aren't greeted by any ads, which is still the preferable option. This service follows the same design language that Google has implemented across the board over the past decade—a minimalist style that uses the colors from Google's branding. We're big fans—the theme ties Google's products together and just works.

When you arrive on the Google Drive landing page, you're greeted by folders

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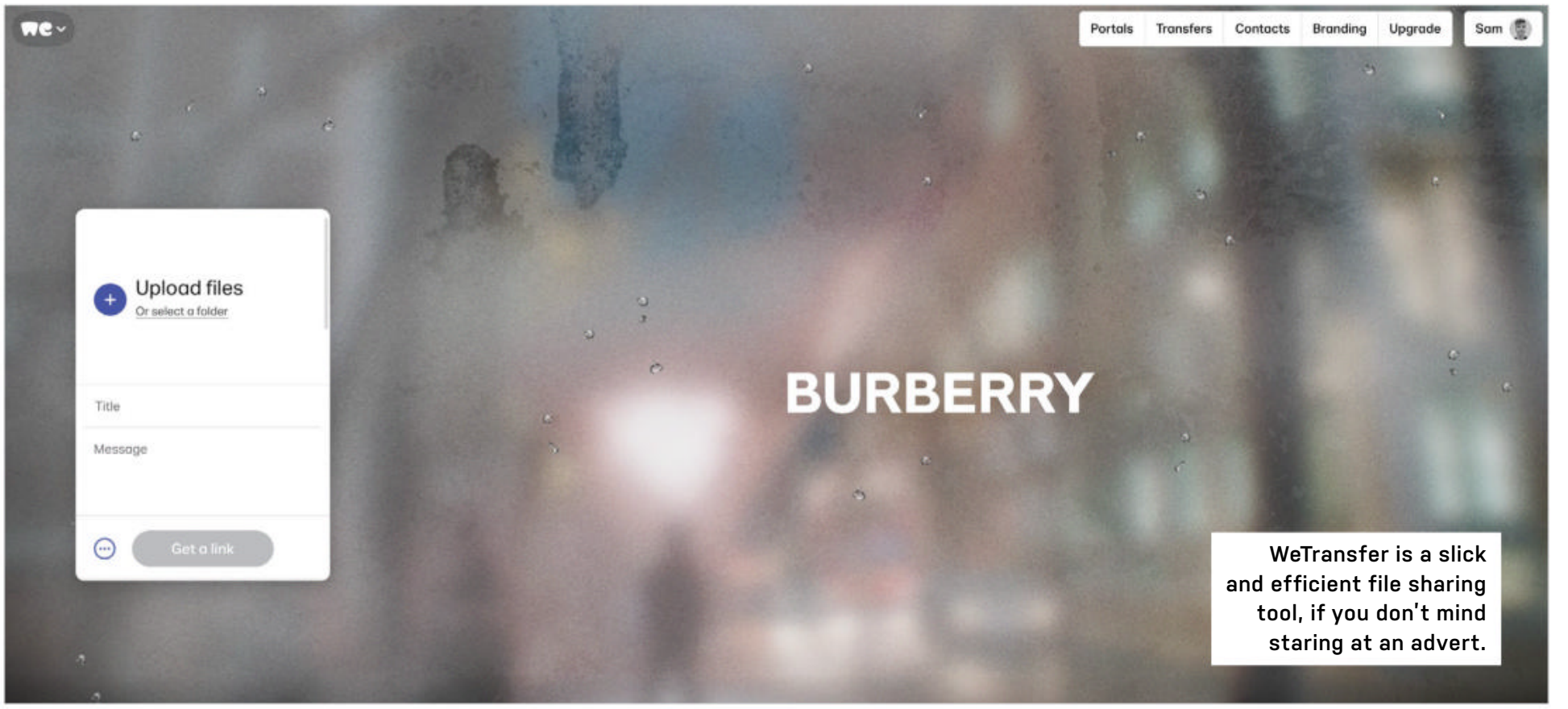

and your most recent files displayed in square icons, making it easy to distinguish recent or frequently opened files. On the left-hand side, there's a list of functions, including your drive, shared drives, items shared with you, recent, starred, and the bin. Above that is the 'new' icon where you can create spaces to upload and share files with others. A large search bar across the top makes it easy to find files, especially as it includes a fine-tuning button to narrow down your search. The top right features your Google account and access to other applications within the Google suite, which is handy.

Despite its solid structure, those who are new to the Google universe may find it takes a while to get used to. On the other hand, WeTransfer makes the whole process extremely simple, while also being easy on the eye, so we have to hand the design element to WeTransfer here.

When it comes to overall features, Google Drive is a much more well-rounded product. It offers you a place in which you can create your own shared file folders, and where other users can then contribute their own files and documents. If you create a folder, you can then choose who else has access to it by inviting people via an email link.

Google Drive is free, but there is a total cap of 15GB, which restricts its usefulness somewhat. The 15GB cap is presumably there to entice you to upgrade to Google One, where you can pay monthly for cloud storage space across the Google Suite all the way from $2 a month for 20GB to $300 a month for 30TB. There are plenty more plans available between these smallest and largest monthly payments, giving you lots of options as you increase the amount of storage you need.

With WeTransfer, you can either get a specific link that you can share or you can send files directly from the WeTransfer homepage. The link expires after one week, during which time it allows the recipient to open and download the files you have sent. Alternatively, you can send files via email from the WeTransfer homepage. You can track your transfer history via the transfers tab at the top right of the page, allowing you to keep an eye on the files you have sent.

Just as Google Drive has a range of pricing options, so WeTransfer has some paid options. The Pro package costs $10 a month and lets you send files of up to 200GB capacity at a time and gives you 1TB of cloud storage. The Premium package is $19 per month and you get an unlimited amount of cloud storage. You also get to send huge files with no limit on the capacity. In our opinion, that makes WeTransfer better value for money than Google Drive. For just under $20 per month, you have unlimited cloud storage and the ability to send huge files across the internet. However, it's evident that Google Drive's free package has many more features than WeTransfer's does.

When testing, we were impressed with the fluidity, effectiveness, and efficiency of both platforms, but more so with WeTransfer. Although WeTransfer offers far fewer features compared with Google Drive, it does have a simple UI that eliminates any clutter, and while you have to put up with adverts on the homepage, they're well-designed and fit neatly with the interface.

If ease of use appeals more to you, then WeTransfer could be a better bet. It prioritizes user-to-user file sharing, whereas Google Drive is more focused on creating a space where you can share files. However, as a free package, Google Drive offers everything WeTransfer does and much more besides.

Although both services are great tools for sharing data, WeTransfer works as a quicker alternative for single files, while Google Drive has the benefit of allowing you to organize your files better. It also makes more sense if you are using other Google productivity services, such as Gmail and Google Docs, as Google Drive can integrate these into your daily life. The well-roundedness of Drive makes it our file-sharing service winner. **–SAM LEWIS**

VERDICT 9

Google Drive

PODIUM FINISH Well-known UI; easy file management; safe and secure.

BURST TYRE 15GB cap; encourages use of other Google services, such as Google One.

$free, Google Drive, Google One 100GB $2 per month to 30TB $300/month, drive.google.com

VERDICT 8

WeTransfer

WELIKE Simple well-designed UI; efficient solution.

WEDISLIKE 2GB file size cap; features adverts.

$free, WeTransfer ,
WeTransfer Pro $10 per month,
WeTransfer Premium $19 per month.
www.wetransfer.com

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LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Remember XMP
> Balancing Builds
> Decoding Hard Drives

MHz Mismatch

I went ahead and built a PC based on your budget blueprint (December 2022), and after doing some research on the CPU (Intel Core i5-12600), I discovered that it did not support the 3,600MT/s DDR4 RAM you'd used in the blueprint.

I therefore had to send the RAM back and re-order the 3,200MT/s RAM that it supports. I just thought you should know so that other people don't make the same mistake! **–D. Yeager**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:
Thank you for contacting us about this issue, and sorry to hear you had problems. You are correct in saying that Intel's website says that its Core i5-12600 CPU supports a maximum DDR4 RAM speed of 3,200MT/s. However, the motherboard we paired it with (the ASRock B660 Pro RS) supports 5,333+ DDR4 memory. Perhaps you used a different motherboard in your build, although most other B660 and Z690 mobos also support faster speeds of DDR4 memory.

The key here, as with nearly all builds, is to go into your motherboard's BIOS settings, update it to the latest version, and then enable XMP (Extreme Memory Profiles) from the memory settings. This will allow you to enable the best compatibility and performance from the memory you have installed.

I hope you purchased your components from an outlet with a fair returns policy, and that you didn't have to spend too much on exchanging your memory in this instance.

Hopefully, you even saved money by going for 3,200MHz memory. The difference in performance between that and the 3,600MHz you originally bought shouldn't be enough for you to notice in most tasks anyway.

Now And Then

You may have missed an interesting analysis in your November issue's *Build It*. I noticed you used the same core components in your $990 Build as you did in your April issue's $1,300 *Build It*. I think it might have been nice to compare the two builds and note why and how you saved $300. I did think the $300 mobo in the April build was excessive! Also, I'm using the Intel Core i5 12400F in my new build and am happy with it.

–R. Matlow

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:
Leave it to our eagle-eyed readers to spot something like this! As pointed out, we used an Intel Core i5-12400 CPU, Nvidia RTX 3050 GPU and 16GB DDR4 RAM in these two builds which we did seven months apart. GPU prices did drop considerably in this time, with the RTX 3050 going from a street price of $560 to an RRP of $320 during that time.

As stated in the letter above, we also went from using a $292 MSI MAG Z690 Tomahawk WIFI DDR4 to a $119 ASRock B660M-ITX/AC motherboard between the two builds. The ASRock was a smaller board and lacked some of the performance and overclocking features offered by the Z690, but saved $170 over the more expensive board, something many people would consider worthwhile.

We also changed up our benchmarking suite in the gap between the older and newer builds, meaning a lot of the test games changed, while we also updated the Cinebench and 3DMark versions we use. However, the two broadly equivalent tests, Cinebench and 3DMark, show similar performance scores between the two systems, meaning we were able to save money without a noticeable impact on performance.

I've mentioned the idea of comparing similar builds to our writer Sam and will make sure we do this in future. We're currently on a tear with next-generation tech from AMD, Intel, and Nvidia in our builds and expect this to continue for a few months. However, when we're doing similar builds using cheaper components, we'll bear this in mind. Thanks again for the suggestion!

Hard Drive Devotion

How about an article on good old spinner HDDs? They're reasonably priced and still used for storage as evidenced by your *Blueprint* build series.

↘ submit your questions to: editor@maximumpc.com

I was going to buy a 4TB HDD and found out there are two different recording technologies—Shingled Magnetic Recording (SMR) and Perpendicular Magnetic Recording (PMR). Is newer always better?

Also, there are drives labeled for Computing, Gaming, NAS, and Surveillance. What is the difference between these? Can any of these be used for data storage on a PC?

A drive for data storage is more important than the primary drive for the OS and programs that can be replaced. Family photos on a storage drive cannot be replaced. I realize you should also have backup copies, but they are probably also going to be on an HDD or a server somewhere. Should data storage be copied to new drives every few years?

It might be interesting to shed some light on the current state of HDDs and perhaps some recommendations.

I've been a subscriber for many years and your articles have given me the knowledge and confidence to build my last two computers. Thanks, and keep up the good work!

–M. Chesta

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:
Lots of people, myself included, can't quite kick the habit when it comes data hoarding. Yes, the latest SSDs are faster, smaller, and more durable than their mechanical equivalents. And while they are getting cheaper, they're still nowhere near a hard disk when it comes to the all-important $-per-gigabyte metric.

As for your questions, starting with SMR vs PMR, broadly speaking, if a hard drive is going into your PC, it's better off being an SMR disk, as they tend to offer more storage capacity and be more energy efficient. PMR disks are more suited to being constantly accessed, achieving high transfer rates, or shifting large amounts of data—NAS environments, mainly. Both the NAS-targeted WD Red and Seagate Ironwolf drives use this technology.

In terms of the different types of hard drives being sold (Computing, Gaming, NAS, and Surveillance), they will all work in your PC, but some are more suited to certain tasks than others. As you've noticed, we recommend Seagate SkyHawk Surveillance drives in our budget and mid-range *Blueprint* builds. They are built for recording security footage, but have a fast 7,200RPM speed and are good value.

In terms of backing up important information, we recommend having both an on- and off-site copy of anything important to you so that if you lose one, you still have the other. Ideally, your local copy will be on a NAS device with some form of redundancy, so that if one drive breaks (which will always happen eventually), you can simply swap it out without losing your data. Any online backup service worth its salt will also offer redundancy as part of the service—you're paying them to keep your data safe, after all.

You didn't mention what you're looking to store, but as you're looking at 4TB drives, I can make an educated guess that it's your personal data, photos, and maybe some multimedia and games. For this, buy whichever drive offers the best level of price per gigabyte you can find, install it on your desktop PC, and then make sure the PC is regularly performing backups of your data to a cloud service such as OneDrive or Google Drive. A future hard disk drive feature is also a great idea, so watch this space!

Single fan versions of the RTX 3050 are available.

GPU Optional

I'm not a gamer, so *Maximum PC*'s emphasis on such machines is of no use to me when I contemplate a new build. I only use PCs for home- or work-related activities and don't want a separate GPU or RGB capabilities, so I appreciate what I'm after is of no interest to many readers.

Nonetheless, I expect there is a small minority of readers similar to myself, who enjoy the magazine because of its interesting articles and software suggestions. If that's the case, please consider covering a robust budget or mid-range build for home or office use.

A few years ago, you also published an issue devoted to building a PC. Would you consider repeating that initiative? **–G. Stevens**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:
Thanks for your message and for reminding us that not everyone wants to run a high-end machine with the latest GPU or RGB lighting configuration. You'll be glad to hear that our designer Fraser has your back on this one, gently reminding me if there's too much gaming in the pages of the magazine.

In my defense, my first issue of *Maximum PC* in March 2022 was a $600 Budget Build, and in April 2021, we had a $400 Build-It Challenge, both of which were tailored to the office PC environment. But with new GPUs and CPUs coming out that redefine the state-of-the-art, that's what we're focused on—we are *Maximum* PC, after all!

Once the dust settles, it will be interesting to see what the latest generation of budget-oriented chips from Intel and AMD can do, and indeed whether there are bargains to be had from previous-generation tech. A "Bang for Your Buck" Build-It Challenge would be an interesting one to set ourselves for those who want a great PC without the gaming features. Thanks for the inspiration!

Small GPU Needed

I've recently returned to computer building. I'm focused on the ITX form factor in custom, artistic cases. Have you recently reviewed smaller graphics cards? I'm looking at cards under 200mm in length usually with a single fan. What are a few decent options for a tight budget? Will they all perform better than the built-in graphics on the Intel Core i5 12600?

–B. Dahr

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:
We've only had one single-fan GPU through our labs in the last year, and that was the PowerColor RX 6400 ITX (September 2022). It's cheap at $159, but we gave it a score of 5 and didn't recommend it overall.

Much better is the dual-fan EVGA GeForce RTX 3050 from our April 2022 issue. It's too big for your build at 202mm, but the good news is there are single-fan versions of the 3050 available from Asus, MSI, and Palit. This is a great card for your machine, allowing you to play most modern titles at 1080p. The downside? While most dual-fan 3050s are around the $300 mark, the single-fan versions seem to carry a $100 premium. With newer RTX 40-series cards hitting the market, you may want to watch out for any sales!

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THE BUILDS

THIS MONTH'S STREET PRICES...

BUDGET

WITH THE RELEASE of the latest generation of processors and GPUs, we were expecting a fall in the price of components this time around, especially in the budget department. Yet, here we are, scanning through all the catalogs, only to find that our CPU and GPUs, on the whole, are much the same price as last month.

We say "on the whole" because the MSI MECH 2X OC Radeon RX 6650 XT 8 GB on the AMD machine saw a drop of around $50 from the previous month's price, so we can't complain about that. Maybe all the new launches raised our expectations for these builds and we're yet to feel the effects of this trickling down into the budget market. Or perhaps we should just be grateful that prices of components aren't still skyrocketing, as they were this time last year. After all, at this price point, you can still grab a fairly powerful machine capable of 1080p gaming.

Due to prices barely fluctuating, both builds remain almost the same, which admittedly, doesn't make for the most exciting blueprint we've ever done. However, one other component that has changed is the RAM. As pointed out by one of our eagle-eyed readers (See *Comments*, page 94), it isn't necessary to use 3,600MHz RAM for our budget machines. These chips can only run at speeds of 3,200MHz, so we have added 3,200MHz sticks into both budget machines instead. If you're using faster memory then it will still probably be supported by the motherboard, just make sure you enable XMP in the BIOS.

On the AMD machine, we swapped out our previous PNY XLR8 Gaming EPIC-X RGB sticks for the equivalent 3,200MHz variant. That also saves us $5, so we may be able to go and grab a coffee once we've finished the build. As for the Intel build, out goes the PNY XLR8 Gaming EPIC-X RGB sticks and in comes Corsair's Vengeance RGB Pro SL running at 3,200MHz. Unfortunately, these cost $9 more, so we'll have to scrap that coffee for now.

AMD INGREDIENTS

PART		PRICE
Case	Corsair 4000D Airflow	$95
PSU	550W Cooler Master MWE Gold 80+ Gold	$60
Mobo	MSI B550M PRO-VDH WiFi AM4	$119
CPU	AMD Ryzen 5 5600X	$195
GPU	MSI Radeon RX 6650 XT MECH 2X OC 8GB	$260
RAM	16GB (2x 8GB) PNY XLR8 Gaming EPIC-X RGB @ 3200MHz **NEW**	$60
SSD	500GB Corsair MP600 PCIe 4.0 M.2 SSD	$65
HDD	4TB Seagate SkyHawk Surveillance 7200	$88
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32

Approximate Price: $974

INTEL INGREDIENTS

PART		PRICE
Case	Corsair 4000D Airflow	$95
PSU	550W Asus ROG Strix 80+ Gold	$70
Mobo	ASRock B660 Pro RS LGA 1700	$109
CPU	Intel Core i5-12600	$230
GPU	Zotac GeForce RTX 3060 GAMING TWIN EDGE OC 12GB	$390
RAM	16GB (2x 8GB) Corsair Vengeance RGB Pro SL @ 3200MHz **NEW**	$69
SSD	500GB MSI Spatium M450 PCIe 4.0 M.2 SSD	$60
HDD	4TB Seagate SkyHawk Surveillance 7200	$88
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32

Approximate Price: $1,143

MID-RANGE

OUR MID-RANGE BUILDS are where we start to see the introduction of next-generation components. At the time of writing, we are still being introduced to the latest parts from both Intel and AMD, and in the previous issue, we brought in new CPUs, which will remain at the helm of their relevant ships.

The AMD mid-range build sports the new Ryzen 5 7600X CPU, which features six cores, 12 threads, and a maximum boost turbo frequency of 5.3GHz. We also have one eye on futureproofing this build, as the RYzen 5 7600X features support for DDR5 RAM up to 5,200MHz, the new AM5 socket, and Zen 4 architecture—overall, it's a highly capable processor and at a reasonable price point too. Of course, by making that change, we had to bring in a compatible motherboard—the Asus PRIME B650M-A AX Micro ATX AM5. This also has support for DDR5 RAM at 5,200MHz and so matches perfectly with our 32GB of Corsair Vengeance DDR5 CL40 that runs at the same speed.

These prices stayed the same, so we didn't see the need to swap them out. However, we did replace the previous NZXT C750 PSU with the same rated Corsair model, giving us a fully modular form factor over the semi-modular one we had previously. We also saved a little money on our GPU, with a sale lowering the price from $550 to $534.

Unfortunately, there were no further changes on the other side of the fence for our mid-range Intel build. However, just as we saved some bucks on the AMD GPU, our Gigabyte GAMING OC RTX 3070 Ti has increased in price from $590 to $630, so it's a case of swings and roundabouts here. Further price fluctuations toyed with our emotions once again, as we realized that the brain behind our build, the i5-13600K, was $30 cheaper than last time. Other than a few changes in prices we mentioned, the PSU was also the only change made here too.

AMD INGREDIENTS

PART		PRICE
Case	NZXT H7 Flow	$130
PSU	750W Corsair RM750 80+ Gold **NEW**	$100
Mobo	Asus PRIME B650M-A AX Micro ATX AM5	$199
CPU	AMD Ryzen 5 7600X	$299
Cooler	Cooler Master MASTERLIQUID ML240L RGB V2	$90
GPU	ASRock Radeon RX 6800 XT Phantom Gaming D OC 16GB	$534
RAM	32GB (2x 16GB) Corsair Vengeance DDR5 CL40 @ 5200MHz	$150
SSD	1TB Crucial P5 Plus NVME M.2 PCIe 4.0	$124
HDD	4TB Seagate SkyHawk Surveillance 7200	$88
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$1,746**

INTEL INGREDIENTS

PART		PRICE
Case	NZXT H7 Flow	$130
PSU	750W Gigabyte P750GM 80+ Gold **NEW**	$106
Mobo	MSI PRO Z690-A ATX LGA 1700	$190
CPU	Intel Core i5-13600K	$300
Cooler	Cooler Master MASTERLIQUID ML240L RGB V2	$90
GPU	Gigabyte GeForce RTX 3070 Ti GAMING OC 8GB	$590
RAM	32GB (2x 16GB) Corsair Vengeance DDR5 CL40 @ 5200MHz	$150
SSD	1TB ADATA XPG GAMMIX S70 M.2 PCIe 4.0	$99
HDD	4TB Seagate SkyHawk Surveillance 7200	$88
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$1,775**

WITH A LARGER BUDGET and an arsenal including the latest performance-focused PC components to play with, our turbo machine blueprints have been far more exciting than the other two. That said, most of the big changes were made in the previous issue, when we introduced Intel's new powerhouse, the Intel Core i9-13900K, and AMD's equivalent Ryzen 9 7900X processors. On the AMD side, we made a total of five changes to the machine last time around and, unfortunately, that means it's not quite as exciting this month.

However, the Radeon 6950 XT GPU is on sale at $800, giving us a tidy saving of $70. We are still awaiting AMD's latest GPUs to compete against the RTX 4090 found on the Intel turbo machine, and although the ASRock OC Formula card is a mighty powerful GPU that is more than capable of 4K gaming, it doesn't stop us from being eager to get our hands on the latest AMD GPUs.

Although we made plenty of changes to the Intel machine last time around, there was one thing we couldn't change back then. Thankfully, we are now in the position to make that pretty exciting swap. Yes, we can finally introduce an RTX 4090 GPU to the mix—boy, have we been waiting patiently for this! We've specifically chosen the MSI Gaming GeForce RTX 4090 24GB as it was the cheapest available of the bunch. We say "cheapest", but in real terms, it's anything but cheap. Costing more than both our budget machines combined, the GPU comes in at just over $2,150. That's a steep price, but it's also a steep performance upgrade with plenty of futureproofing too, considering the lifespan of the previous card and the longevity the RTX 3090 Ti still has today.

This pushes the overall cost of our Intel turbo machine up from $3,397 to $4,112—although that's somewhat inevitable when you dangle new top-tier components in front of tech enthusiasts. On the AMD side, the overall cost falls from $2,710 to $2,671. That's quite some disparity between the two turbo builds, but this should change when we get the new AMD graphics cards in.

AMD INGREDIENTS

PART		PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$190
PSU	1000W NZXT C1000 80+ Gold **NEW**	$180
Mobo	ASRock X670E PG Lightning ATX AM5	$260
CPU	AMD Ryzen 9 7900X	$550
Cooler	Cooler Master MasterLiquid ML360R RGB 66.7 CFM 360mm	$145
GPU	ASRock OC Formula Radeon RX 6950 XT 16GB	$800
RAM	64GB (2x 32GB) Corsair Vengeance DDR5 CL40 @5200MHz	$280
SSD	1TB WD Black SN850X M.2 PCIe 4.0	$135
HDD	6TB WD Blue 5400 HDD	$99
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32

Approximate Price: $2,671

INTEL INGREDIENTS

PART		PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$190
PSU	1000W EVGA SuperNOVA 1000 GT 80+ Gold	$155
Mobo	Asus TUF GAMING Z690-PLUS WIFI DDR5 LGA 1700	$235
CPU	Intel Core i9-13900K	$660
Cooler	NZXT Kraken X73 73.11 CFM 360mm	$185
GPU	MSI Gaming GeForce RTX 4090 24GB **NEW**	$2,160
RAM	64GB (2x 32GB) Corsair Vengeance DDR5 CL40 @5200MHz	$270
SSD	1TB WD Black SN850X M.2 PCIe 4.0	$135
HDD	6TB WD Blue 5400 HDD	$90
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32

Approximate Price: $4,112

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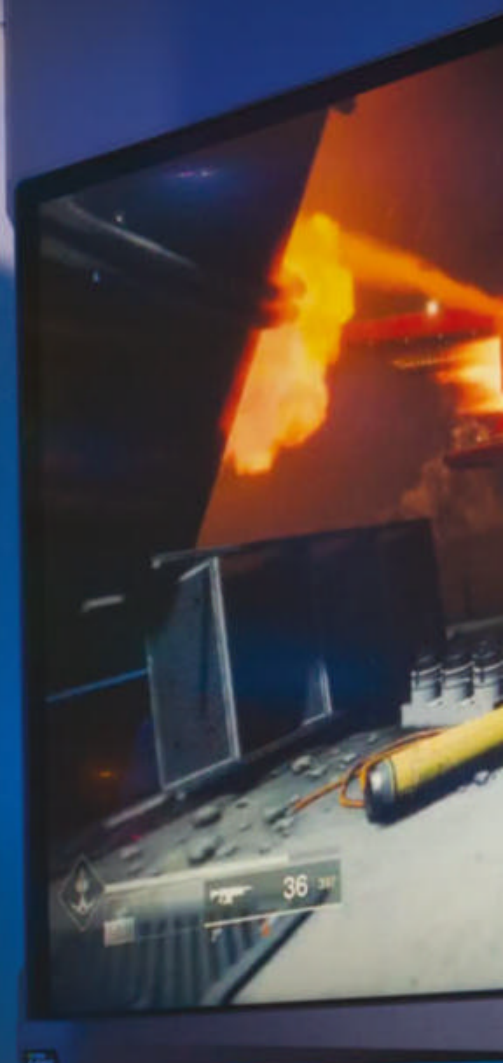

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